COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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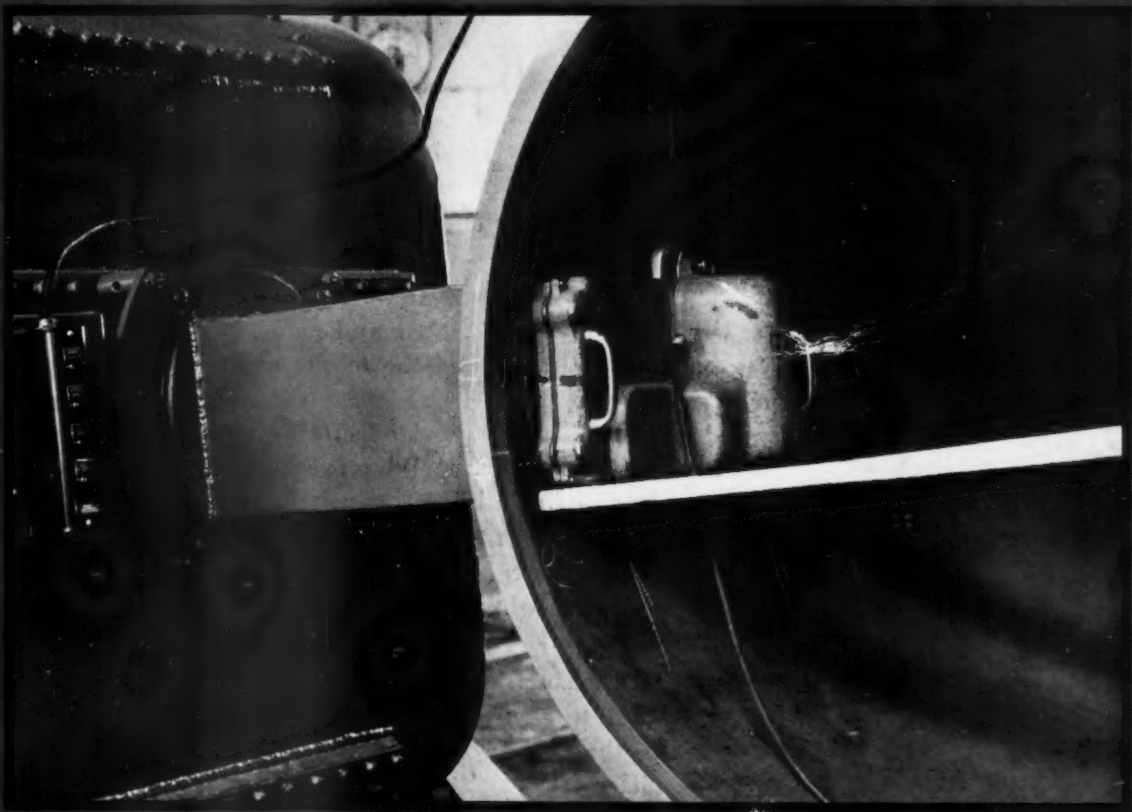

Making an X-ray exposure of a welded boiler drum before head has been attached

Pipe Welding Procedure at Conners Creek

Combustion Control and Controllers

Estimating Grindability of Coal

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VOLUME SEVEN NUMBER NINE

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FOR MARCH 1936

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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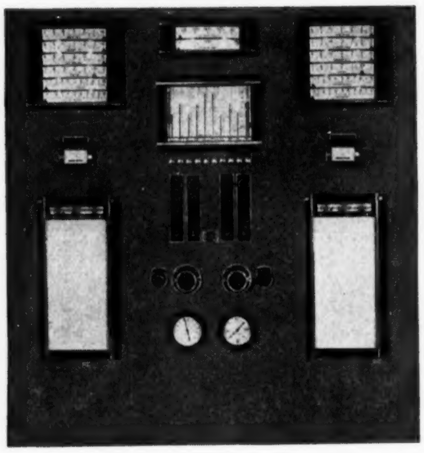


EDITORIAL

Midwest Power Conference

It has been several years since the last Midwest Power Engineering Conference was held. In the interim many advances have been made in power plant practice and, in some respects, new economic conditions prevail in the field. Therefore, the forthcoming Conference, which is scheduled for April 20 to 24 in Chicago, is timely.

Cooperating in the Conference will be the local sections of the national engineering societies and the Western Society of Engineers. An attractive program of twelve sessions and thirty-five papers by leading engineers has been arranged. Among the topics to be discussed will be research, the economics of power supply, superposition, fuels and furnaces, trends in boiler design, corrosion, turbine operation and the interchange of power and steam between public utilities and industrial power plants.

Inasmuch as the Third World Power Conference, which is to be held in Washington early in September, will not consider the technical aspects of power plant design and operation but rather the broader problems of power supply, regulation and government planning, the Midwest Conference holds particular interest for those concerned primarily with technical matters.

During the depression years the number of large engineering meetings was greatly curtailed because of the expense involved in putting on such meetings and because of the doubtful attendance. With a resumption of activity in the field normal attendance should again be anticipated. The present situation, however, does not warrant the planning of too many meetings and too extensive programs. It will be recalled that during the halcyon days of '28 and '29 meetings and programs were arranged out of all proportion to technical developments in the field. Extent of the program rather than quality prevailed and much adverse criticism often resulted. Caution against a repetition of this mistake is in order. It is believed, however, that the Chicago Conference will be welcomed by many engineers as an opportunity to get together and to discuss mutual problems of more recent origin.

Interpreting the TVA Decision

Since the recent TVA decision was rendered by the U. S. Supreme Court discussion has been rife between the advocates and the opponents of federal power activities. The former assume that the principle involved in this decision applies also to other regional developments, while the latter point to the fact that the decision was very limited in scope, the Court having passed upon only the validity of the TVA Act, the right to construct Wilson Dam under special war powers and the right to dispose of surplus power therefrom. They cite the statement of Chief Justice Hughes that the social program was not before the Court, that judicial power does not extend to abstract questions and that the case in point was limited exclusively to Wilson Dam power contracts. From this it would appear that the court in thus specifically limiting its decision to the conditions peculiar to Wilson Dam did not intend that the ruling be construed as having general application.

Meanwhile, late in February the Fourth Circuit Court of Appeals in North Carolina reversed the ruling of a lower court and upheld the right of the Government to provide funds for construction of publicly owned and operated hydroelectric projects as part of the PWA program. This is to be appealed and a decision will ultimately be forthcoming from the Supreme Court.

Interpreting these decisions as a victory for its side, the Government is reported as planning to press its regional programs in the Northwest and the Mississippi Valley. With so many questions yet to be settled by the Supreme Court, precipitate action by the federal authorities is certain to involve vast expenditures of public funds that may be invalidated in part or completely by adverse decisions.

The whole matter is still very much "in the air" and it is likely that many months will elapse before a definite course may, with certainty, be charted. Whatever the final outcome, it can have little immediate effect in meeting increased electric demands in various localities which obviously must be supplied by steam power.

Not a True Index

A most interesting interpretation of power output figures by W. M. Carpenter, economist of the Edison Electric Institute, appears in the February *Bulletin* of the Institute. It has been customary to consider electric output as an almost infallible index of industrial activity and the marked increase in electric load during the past year has, in general, been so interpreted. The author points out, however, that although the present load is ten per cent above that of 1929, industrial production, as reported by the Federal Reserve Board, is still twenty per cent below the 1929 average. This discrepancy is attributed to the fact that electrification of industry has gone steadily forward since 1929 and that the domestic load has grown approximately sixty per cent during the past seven years.

Mr. Carpenter also explodes the popular fallacy that improvement in output is paralleled by a similar improvement in utility earnings, rate reductions and heavier taxation having combined to disturb the relation between output and revenues.

Another factor, not mentioned by Mr. Carpenter, but which may be taken as indicative of greater industrial activity, is the very considerable new private power plant construction now under way, especially among some of the larger industrials. This, of course, would not be reflected in the central station output figures. However, Mr. Carpenter's analysis as concerns output not being a true index of industrial activity is indisputable.

COMBUSTION CONTROL and Controllers

By HARVEY C. MITTENDORF
Combustion Engineering Company, Inc.

Beginning with an explanation of the simplest type of regulation, such as is employed in the house-heating boiler, the author leads up through the various degrees of control to the more complete systems as employed on power boilers in industrial plants and central stations. Numerous well-known types of combustion control are classified but no attempt is made to describe each in detail; instead, the discussion is confined to the principles upon which they operate and adaptation to stoker, pulverized-coal, gas and oil firing.

WHEN we think of "Combustion Control" we picture a more or less elaborate system; the more extensive our combustion experience, the more likely are we to overlook the stove where combustion is regulated by the simple contrivance called a damper.

The damper is a combustion controller extraordinary. It may assume several forms but its function is always the same—a means to regulate flow. However, other devices such as a fan operating at varying speeds will also regulate flow. Consequently, for the purposes of this article a damper will be broadly defined as any device which operates to control the volume of air entering, or gases leaving, a furnace. As the damper, thus defined, does not in itself have any intelligence, it is not viewed as a controller. Instead, those devices which cause it to move comprise what are classified as combustion controllers. The extent to which controlling devices are applied to give increased sensitivity to the various damper motions determines the elaborateness of the combustion control system.

If the present consideration of the control of combustion is to be complete it will be necessary to separate it into units covering fires presided over by persons whom we may present as

(*a*) The average householder
(*b*) The apartment house janitor
(*c*) The industrial fireman
(*d*) The boiler plant engineer

Each has a combustion control problem, i.e., a problem in chemical combinations which is to be answered by damper control within limits dictated by the size and type of furnace. The problem of each is similar. Differences exist but largely they are differences of degree, not kind. The accuracy of the result which can be obtained in each case is limited almost entirely by the extent to which controlling elements are initially installed, and then carefully maintained.

Let us examine the problem of these four individuals and see what material may be available to give the answer to their problem.

The average householder is concerned with getting as many heat units as he can per ton of fuel fired into the air in his home. He doesn't express it that way though. He thinks in terms of temperature. Experience has taught that an air temperature of, say, 70 F most nearly meets his average requirements and he must burn enough fuel to satisfy this want. Also, if he increases this temperature his pocketbook suffers extensively. He wants therefore a combustion controller which will regulate to these temperatures. Such apparatus is available in the room thermostat—standard material, inexpensive and easy to apply. As the furnace of the householder is usually a simple firepot, the only mechanical item which must be controlled to regulate the combustion rate is the uptake damper. The opening or closing of the uptake damper does not in itself give combustion control; the fire must be in condition to respond to the change in furnace draft, there must be reasonable freedom from ash on the grate bars, fresh fuel in the right proportion, free flow of air to the ash pit, suitable thickness of fuel bed and the other essentials for a good fire. If these requirements are provided, then though the furnace be banked at first, good combustion will be obtained quickly when the damper opens and in a short time the efficiency of combustion will be close to that which can be obtained with more elaborate installations.

Thus, to the householder, combustion control implies little beyond a thermostat and a motor operated damper—with an added safety device to avoid excessive water temperatures or steam pressures. This type of combustion control is more frequently designated as temperature control.

In recent years the introduction of mechanical coal and oil burners has extended the householder's combustion control horizon. In most instances, a fan to supply the necessary air for combustion has been included with these automatic burners. As the fan operates at a constant speed a fan damper is a necessity, and the combustion control must provide air at the rate corresponding to the fuel feed.

In both the simple furnace and the more elaborate mechanically fired furnace for the home the essential

element under control is the uptake damper. If the fuel feed is also controlled, then the undergrate or equivalent air flow damper should be under control.

In Fig. 1 is shown a desirable method of connection of simple equipment suitable for the hand-fired boiler for the home. The sketch has been drawn in the position when the thermostat is calling for heat. Thus the uptake damper is closed tight. No other chain than that to the uptake damper from the damper motor is essential. However, it is easy to make the additional connection to the undergrate damper. If the boiler has a pressure bellows an added protective feature is readily incorporated as indicated by the dotted lines. The bellows lever may be connected only to the uptake damper or a second chain lead may be taken to the damper motor, thereby having the undergrate damper chain operate from a pulley hanging in the bight of the first chain. This simple and inexpensive control is available to practically all those burning nut-sized hard coal, coke or other solid fuels not subject to excessive caking at very little cost.

Numerous modifications of this arrangement are possible. Small sized anthracite may need a blower for forced draft. In that case a relay may be operated from the room thermostat, the relay contacts handling the motor circuit of the blower. The pressure bellows is then preferably connected into the motor circuit interrupting it on high pressure and stopping the blower. This is basically the connection used with screw-feed stokers, oil burners and burners utilizing gaseous fuels. In the case of the last two it is also customary to employ means for interrupting the electrode circuit after ignition has taken place, and if this should be delayed to stop fuel supply. These devices are operated from stack temperatures.

In this control field the products of such firms as Minneapolis-Honeywell and Detroit Lubricator are common.

In all low-pressure heating installations the elements of control are essentially those of the household equipment. The increased size of the installation for several family houses and apartments simplifies the requirements in some respects. The vapor or steam system of heating is universally used. The boilers are likely to be under the supervision of the janitor whose "other duties" prevent too close observation of the fires. The tenants demand hot water and heat much as the householder and the period of heavy load is just as likely to be at the same hours as those of the householder.

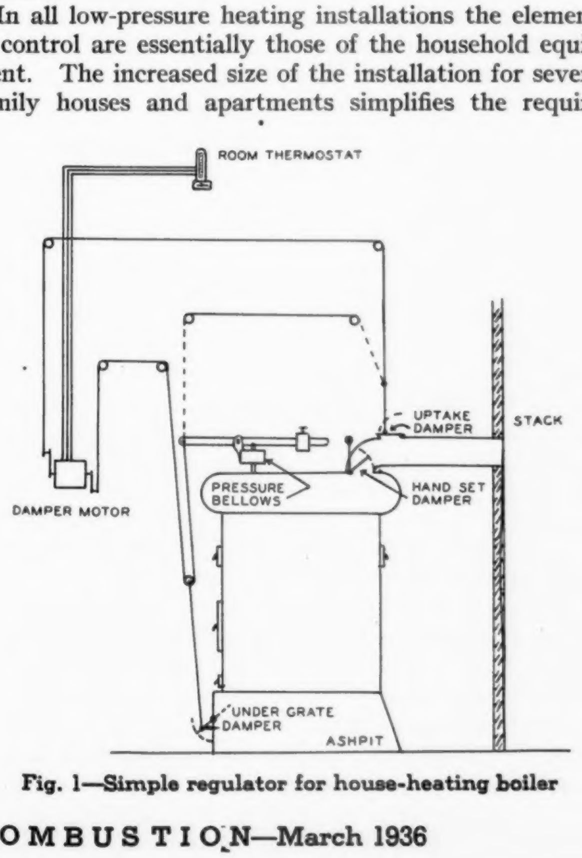


Fig. 1—Simple regulator for house-heating boiler

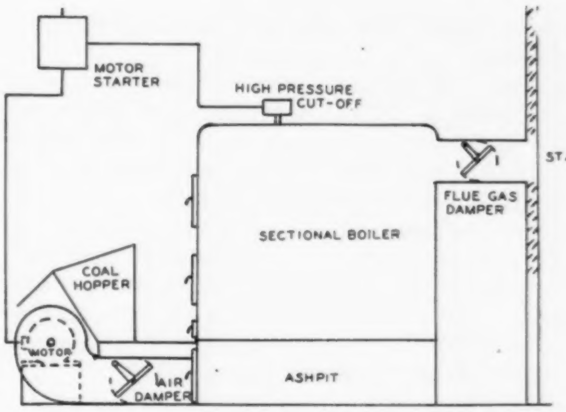


Fig. 2—Simple controller for stoker-fired boiler

The "other duties" of the apartment-house janitor range from radio fixing to installing new window panes. Not often can he stick to these jobs in the winter until they are finished, if he is to be a satisfactory fireman. Because of the many radiators to which steam is to be delivered, a thermostatic method of combustion control is not feasible. Instead of temperature regulation, however, steam pressure regulation can be substituted, moving the dampers to hold the desired pressure either by electric motor mechanisms or bellows devices of a size that will be easily expanded by the low steam pressure. But, although such combustion control may hold the desired steam pressure while there is fuel in the furnace, a solid fuel will not last long unless a large quantity has been fired. Such manner of firing usually prevents economical operation, so a mechanical means of supplying fuel is a necessity if reasonable efficiency is desired. The apartment-house installation, therefore, preferably uses equipment to supply fuel and air and control to furnish these and to remove the gases. Simple equipment to control these items is available in pressure-responsive contacting devices.

In Fig. 2 is illustrated the simplest type of a controller using only a high-pressure cutoff for a furnace fired by a stoker. The flue gas and air dampers are manually set to those positions which experience has shown as correct for any pre-set coal feed. In the sketch the lever controlling the rate of coal feed has not been included. It will be clear that active combustion will occur only while the motor is running and supplying fuel and air and that when the steam pressure has increased to that point where the cutoff switch is thrown that the motor will stop. There will continue to be a high furnace draft at this time but the reduced combustion rate will soon drop the gas temperature and cause the fire to gradually cool.

This arrangement in the simple form shown is not inclusive and has numerous disadvantages but if the low investment cost in control is considered it provides a degree of regulation not otherwise obtainable.

Modifications of this control are to be found in the

industrial boiler field and will be discussed in later paragraphs.

Thus far "off" and "on" control has been considered. That is, when an active fire is demanded we are calling for the maximum heat release of which the equipment is capable at the moment and are providing for no intermediate settings except as such setting is provided by some hand adjustment. Some may object to calling this combustion control. In its field it is, however, a very desirable and satisfactory combustion control although it lacks those niceties which are obtainable with controllers that position themselves in accordance with the demand.

Control of Industrial Plant Boilers

In the industrial field we more nearly approach the ultimate in combustion control. This field is a wide one, ranging from a point only one step removed from the apartment house to just below the elaborate central-station equipment. Here one enters into the field of the power boiler. Steam pressures demand a higher type of personnel. Instruments at least of a simple type are usually found to aid the personnel. Hand firing has been superseded by some form of automatic firing. Forced draft is an adjunct and induced draft may also be present. In addition to the higher steam pressures, superheat may be involved. The boiler room engineer appreciates most of the factors in the combustion problem and is likely to have studied the various combustion controller types and to have decided preferences.

The gas flow in an installation of this type is best regulated in accordance with steam flow. The regulation may be by damper position, induced-draft fan speed or better still a combination of the two. The steam flow may or may not be measured. The steam pressure serves to actuate the master element. Fuel feed, being intimately associated with gas flow, is also regulated by steam pressure. In order that furnace leakage may be held to a minimum the furnace draft is held to that value which is required to remove the gases properly. Combustion air must be supplied to the furnace in right relation to the fuel and the controller supplies the air in the proper quantities. As with induced draft, control is through forced-draft fan damper regulation, fan speed or by both speed and damper position.

In any particular installation, all of these regulating elements may not be required. On the other hand, when facility for burning mixtures or alternative fuels is necessary, other regulators are required. While additional regulators may complicate the whole system, the elements for any part are the same as if the other regulators were not present.

There are no fixed rules as to how much of a complete regulating system should be installed with industrial boilers. Until a decision is made on how much one can afford to spend no final arrangement of the parts of the system can be made. One may have to be satisfied with a steam-pressure regulator, or a pressure regulator and furnace-draft regulator, or the latter two combined with an instrument actually metering the gas flow. With some types of firing equipment, the distribution of air will actually have to be left to the fireman; perhaps, also, the rate of fuel feed may best be left to his judgment.

When the number of boilers in a plant makes it necessary to operate several units to carry the load, and particularly when these are of different capacities, we near the final phase for an automatic combustion installation. In this case it is imperative that the control provide so that the entire group of boilers may be operated at the will of the boiler plant engineer. He may desire to have all boilers meet the load swings in relation to their capacity or he may want several boilers operating at a fixed rating with load swings on other boilers, or he may want the load swings distributed over several boilers but distributed unevenly. Such requirements impose the necessity of a master combustion controller which may dictate to each individual controller but at the same time permit adjustment at will of the individual boiler controller. These systems may become complex, especially if two or three fuels are involved per boiler.

In earlier paragraphs there was cited broadly the approximate requirements of a combustion controller for each type of installation. Manifestly, specific consideration must be given to each installation. Special requirements in any case may considerably vary the items which should be controlled. Since, the units which go into a complete combustion system have some features in common it may be well to consider a few of the general types and note how the parts are combined to form a system for some of the installation types which have been previously outlined.

It has been pointed out that with heating installations the controller is of an "off" and "on" type; that is, when heat is called for and the controller is "on" the equipment is set for the maximum release of heat. With natural draft an interval of time may be required to build up to this maximum release, but this is a delay for which the controller cannot compensate. Conversely, when the "off" period occurs the position is changed to give the minimum heat release. With a hand-fired furnace, the controller opens the stack damper to its wide open position, at the same time closing the check damper and opening the ashpit damper. With an oil- or stoker-fired furnace with forced draft a similar operation occurs, the stack damper is set to remove the gases, and at the same time the fuel and air delivery are started by energizing the operating motor.

These controllers are almost exclusively of the electric-motor-operated type. They lend themselves particularly well to heating installations as usually no other motivating power is available. With such source of energy it is easy, too, to introduce safety precautions such as high-pressure and low-water cutouts, water feeders and stack relays for ignition cutoff. The present discussion is not directly concerned here with these protective features nor with the several methods that are employed to avoid the loss of ignition with automaticallystoked fires during the "off" time.

It is in the power boiler field that one finds the systems so often mentioned in technical literature, namely, Smoot, Hagan, Bailey, Leeds & Northrup, General Regulator, etc. In the smaller of these power boilers—say, up to 300 hp—is where we can begin to draw the line more definitely between pressure regulation and combustion control. But how can pressure regulation be obtained except by

combustion control? Of course, it is necessary to control combustion in order to attain pressure regulation, so how then shall we differentiate between a pressure regulator and a combustion controller? We shall probably have to set our own definition. But first we must survey the possibilities of each.

We know that in the process of burning a fuel of certain analysis a definite weight of gas is produced; also that it is impractical to utilize in combustion only that weight of air which is theoretically necessary for combustion, and that at different ratings the excess air which purposely or accidentally is admitted considerably influences the weight of gas which passes to the breeching. Then, too, the boiler exit temperature is not a constant so the volume of the gas is a variable. These variables in themselves make it impracticable to set the boiler damper at a fixed position and the possibility of such a setting is further prevented by the change in stack draft from hour to hour occasioned by changes in outdoor temperature, wind direction and other meteorological conditions. Hence, if we are to maintain correct draft conditions in the furnace it becomes necessary in some way to regulate the damper setting, accommodating its position to the gas volume.

Combustion Control vs. Pressure Regulation

For the same reasons that one cannot have a fixed damper position for all ratings it is also impracticable to have pre-set damper positions for particular ratings. And in the manner in which the controller provides facilities for meeting this condition is perhaps to be found a definition between a pressure regulator and a combustion controller.

As a theoretical conception, it may be said that for a certain weight of steam one must stoke a definite weight of fuel and to burn this practically requires a definite weight of air. Also, at any rating there will be a specific weight of air filtering into the setting. The summation of these items will produce a certain weight of gas and if the boiler is clean this gas will have a readily calculated volume for the expected resulting exit temperature. This is elementary mathematics and nothing is left to chance. Theoretically, therefore, the fuel may be regulated to the load, the air to the fuel and load, the flue gas to the fuel and load, the damper position to the gas—all by one instrument responsive to load or, as previously noted, to pressure.

One pressure regulating device of satisfactory size can readily accomplish the desired settings with but slight variation of pressure from that which it is adjusted to maintain. Why not call it a combustion controller? The trouble is with the basic theory that the elements entering into the problem are constants. Actually, the fuel composition may vary, the air temperature changes, the boiler becomes dirty, the gas weight increases because of lowered efficiency, the exit temperature is raised and all these upset the balance. A combustion controller should correct for at least some of these variables. The extent to which it compensates is a measure of its completeness and, other things being equal, of its value. But this is not to say that a pressure regulator only is not a desirable adjunct to any boiler room, and especially for small units.

Despite the objections cited to the use of one pressure regulator for three-point operation, it is an approach to

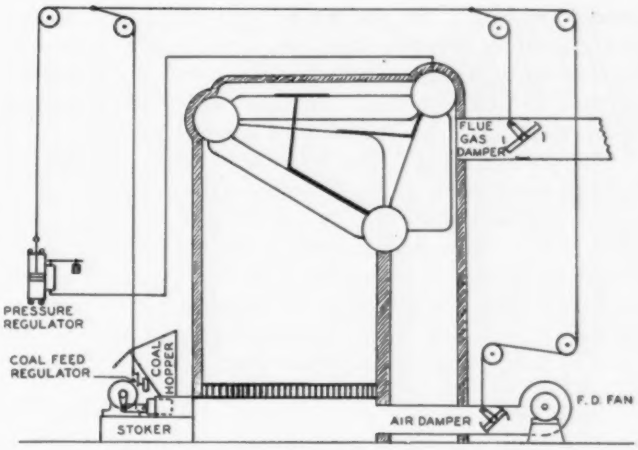


Fig. 3—Pressure regulator for three-point operation

a controller which will overcome some of the difficulties inherent in the mode of control shown in Fig. 2 with but a slightly greater investment. Fig. 3 shows such an arrangement. Its biggest advantage lies in elimination of on and off regulation and the substitution of equipment whose action is commensurate to pressure variations. Thus any change in pressure from the desired value causes a slight piston displacement which, in turn, changes the coal feed and damper positions. There are a number of controls of this general design available. Carrick, Askania, Shallcross, Ruggles-Klingemann, Ajacks, Brooke are but a few of them. Some have hydraulic pistons, others electric motors; the choice of design lies with the purchaser. The essentials are rugged, simple construction and ease of maintenance. Qualities such as sensitivity and freedom from hunting may well be sacrificed for the former qualities. The average engineer will not long baby a controller which is forever failing. On the contrary, he is quite partial to one which is always in service even if it does not give him hair-breadth accuracy.

There is an easy way to overcome part of the difficulty which has been presented by the failure of simple pressure regulation to serve all needs. Suppose the furnace draft is controlled from a separate instrument and that it may react either on the uptake damper or on the damper controlling air to the furnace. This furnace draft regulator in conjunction with a pressure regulator may be taken as the dividing line for our definition of a combustion controller and a simple pressure regulator system. It is, of course, desirable to add other devices in more elaborate installations.

Compressed air, oil and water under pressure and electricity are the power sources used in the elements of a combustion control system. Smoot and Hagan have used air, oil and water. Bailey and Leeds & Northrup formerly utilized electricity but are now offering pneumatic types. Whether from manufacturing reasons or otherwise the types employing cylinders to move dampers in preference to electrical motors seem more popular at present.

Since a combustion system is a combination of essentially standard regulators, it is helpful to have in mind these elements so as to see later how they are combined into an operative system.

The master pressure regulator is a spring or weight loaded diaphragm; its position is responsive to steam

header pressure. In pneumatic systems it is a sender to transmit air pressure impulses to the various receivers. In electric systems it establishes the value of the control current to the receivers. In one case a pilot control valve is adjusted, in the other a control rheostat.

The furnace-draft regulator is a sensitive balance with pressure bells partially immersed in oil, the under side of one bell connected to the furnace, the other side open to air. Movement to unbalance the beam actuates a control air valve or engages up and down electrical contacts. These send forth the impulses to the receiver under control. In various ways the bells may be set so as to hold a constant furnace draft or the bell loading may be set to be adjustable with boiler load.

Recent Modification of Hagan design

We might note here a recent Hagan modification of the conventional design. The under side of a diaphragm regulator is connected to the furnace, the other side to atmosphere. The diaphragm is loaded by an adjustable spring. Change in pressure on the diaphragm moves a sensitive valve permitting an impulse pressure to be sent to the receiver and to a collapsible bellows within the instrument. This bellows encloses oil within which is a close-fitting piston. An adjustable leak port permits the oil to flow from one side of the piston to the other and the rate of flow establishes the speed with which the diaphragm recovers its position. By a change in connections to the diaphragm so that this is attached to a pipe, which has a Hagan leak valve on one end and a Hagan fractionating valve on the other, graduated uptake damper control may be had. The fractionating valve end is connected to the boiler uptake and the leak valve is loaded from the master sender. Adjustments at the fractionating valve provide means to regulate the furnace draft through any desired range.

The fuel-feed controller receives its instruction from the master regulator. In the cylinder-operating types movement continues till the calibrated rate of fuel feed provides a condition equal to the loading pressure obtained from the master regulator. The feed controller is then in balance and the new setting of the controller is that necessary for the changed boiler load. The electrical types employ motor drive to change the rate of fuel feed, follow-up devices such as fan or electric tachometers providing the necessary reverse loading.

The receivers which control damper positions are similar to the fuel feed controllers. They move only in accordance with the dictates of the master which controls them, increasing or decreasing the damper opening as necessary. Where installation is made on units with variable-speed mechanical draft fans the receivers are often fitted with auxiliary devices to cause the power drives of the fans to be raised or lowered in speed whenever the damper position moves beyond predetermined limits. The purpose of this is to obtain the benefit of operating the fans at those speeds wherein economy of driving energy is obtained. Thus a fan is prevented from running at a high speed when the damper may be nearly closed.

Refinements in installations of the above elementary controllers are frequently introduced in one way or another. This is especially true in cases where the master controller is to serve more than one boiler. Accepted practice for such instances is to provide a station control panel and an individual panel for each boiler. On the individual panels facilities are provided for local manual control or operation at different ratios than those dictated by the master. Loading devices of some type are included to permit changing, say, the ratio of air to fuel at the will of the operator. In instances where the connection of a single static pressure tube to determine the flow of air or gas is not elaborate enough to produce the desirable accuracy of controller setting, manufacturers employ differential pressure connections actually metering the flow and adjusting from these metered values.

For this purpose the boiler is viewed as an orifice, with the two static pressure connections as the upstream and downstream connections of the usual meter. One connection—the downstream one—is usually made at the boiler exit; the upstream connection perhaps in the furnace or more frequently at some point in the boiler passes.

While the details of the individual parts of control systems may differ extensively for any two similar installations, the mode of control is not often greatly different. Therefore, some basically typical installations may be examined to advantage. This was done in the case of heating boilers with thermostatic or pressure control; and further discussion will therefore be limited to power boilers. As such boilers today are invariably stoker-, gas-, oil- or pulverized-coal fired, the study can be divided conveniently into three main divisions. These with one or two subdivisions will serve to cover the principles employed. Combination systems, as previously noted, are mixtures, the complication of the mixture increasing with the number of fuels included. These will not be considered in this article.

Application of Control Elements

Stoker-fired furnaces naturally fall into two classes, traveling grate and underfeed types. The nature of the boiler, whether straight or bent tube, or the nature of the baffling, whether cross or longitudinally baffled, is not a control problem, except to locate properly the air or gas flow connections.

Traveling grate stokers have zoned air compartments, each zone controlled by dampers, the settings of which are made in accordance with no simple rule. Although attempts have been made to connect these dampers to automatic controls results have not been generally satisfactory. The accepted practice is to regulate stoker feed in accordance with steam pressure master control. The loading impulse is sent from the master panel to the individual boiler control panel, thence to the fuel-feed controller. This increases or decreases the potential heat release from the grates by speeding or slowing the rate of grate travel. No control is applied to the gate which determines the fuel-bed thickness. This gate is hand set. However, the transmitting impulse is also relayed to the air-flow controller and to the furnace-draft controller, assuming the latter is not of the constant draft type. The change in loading on these elements unbalances them just as the fuel feed was unbalanced. To re-establish the air-flow balance the boiler exit damper is re-positioned by its damper-operating device. This changed setting modifies the furnace draft and the wind-box air damper is reset by the dictates of the furnace controller through its damper

operator. As has been noted, however, this latter action only changes the air pressure in the windbox to give total air flow as demanded to meet furnace draft. Whether a change is necessary in the position of the dampers in the six or more compartments must be left to the boiler attendant.

The action of the equipment with an underfeed stoker is not unlike that just described. Except in special cases, there is no zoning of the air compartments, consequently attention to compartment pressures is not required. The necessity of maintaining an essentially similar fuel bed across the furnace takes its place. The boiler attendant's care must therefore be given to the several pushers and it becomes one of his prime duties to see that coal is properly distributed across the furnace. With any stoker the responsibility of a proper fuel bed must remain with the individual, not with the mechanical regulator.

If motor-driven draft fans are part of the installation the damper operators may include auxiliary means to change the speed of the motors. These means are often contacting devices of a type whereby the adjustable-speed motors are set to a higher or a lower speed by rheostat position or other electrical change. When the limit of speed regulation has been reached further control of air or gas flow can only be by continued damper movement. Within the limits of drive regulation the speeds are usually kept close to a minimum and damper opening near the maximum in order to conserve fan power. However, adequate leeway is necessary so that a sudden increase in boiler load will not cause a too rapid demand for more power, else motor circuit-breakers may open and loss of all power will result.

With steam-operated fans a similar auxiliary control for the turbine throttle valve is used. Here, however, there is no question of power failure occasioned by too rapid acceleration, and to that extent turbine drive is simpler from the control standpoint.

In Fig. 4 is shown the elements of a combustion-control system applied to a traveling grate stoker. A master regulator is connected to the steam main. The sending air pressure to the receiver regulators is through a valve in the master, this loading pressure being transmitted

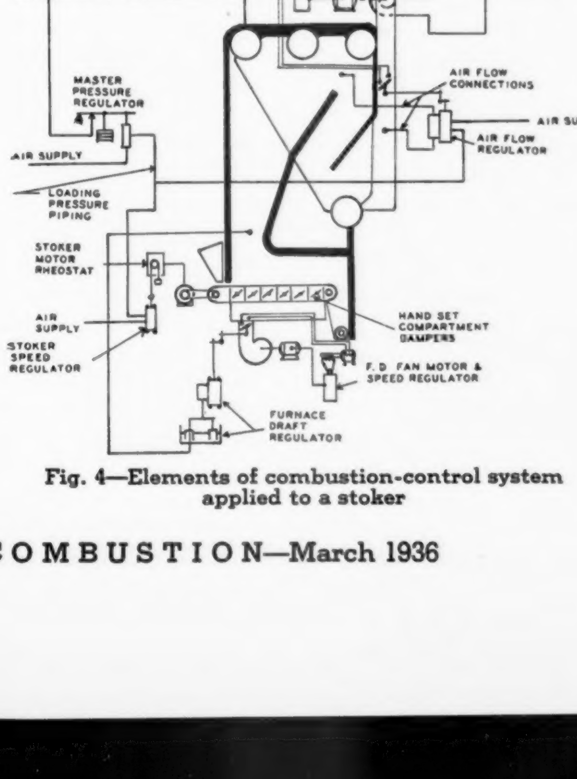


Fig. 4—Elements of combustion-control system applied to a stoker

to the fuel-feed and air-flow regulator as shown. The fuel-feed regulator changes the speed of grate travel as required to supply the amount of fuel required. At the same time the gas flow regulator is unbalanced to cause a change in uptake damper position and this is reflected in furnace draft change. However, the furnace-draft regulator is set to hold constant conditions in the furnace so that it moves the forced-draft dampers to increase or decrease the flow of air.

This air flow change reacts on the differential draft connection in the gas-flow regulator causing it to balance its beam against the impulse received from the master regulator, and when this is accomplished the entire system is again in balance and further change does not occur until there is again a change in steam pressure.

If in their travel the uptake damper and air flow dampers require changes in fan speeds, they operate on electric circuits to change the motor-speed regulators. It is usually desirable to include dampers in the gas and air ducts as shown instead of providing a change in flow exclusively by fan speed changes. Where sudden and extreme load changes occur this is imperative, for the time required to vary the fan speed may be too long to enable the control to stabilize itself before another change in header pressure occurs. The interposition of the damper having practically no inertia permits the control to move as required, the fan speed following more leisurely.

Variations Involve Complications

In installations where it is desirable to increase furnace draft with increasing ratings, the master sending pressure may also be connected to the furnace regulator. It then acts to provide a new draft setting for each rating. Similarly, it may be desired to operate with higher excess air at some ratings than at others. This necessitates other modifications. The manner of accomplishing all these variations involves complications which are beyond the scope of this article.

Although Fig. 4 is drawn to illustrate the general application of control to a traveling grate stoker, the arrangement may be generally applied to an underfeed stoker as well.

In general, the combustion control manufacturers have preferred to connect the control of the forced-draft unit into the furnace, although this is by no means a universal connection. It is not unusual to find the furnace draft regulating the uptake damper, and many operators prefer this connection.

When the furnace is gas fired the fuel-feed controller regulates the gas flow through a valve or damper. If the gas pressure ahead of the valve is fairly constant, the fuel-feed controller alone is adequate to the combustion regulation required but frequently the use of gas is as an auxiliary fuel. The pressure may then vary over wide limits and this necessitates another damper installation to maintain an approximately constant gas pressure ahead of the fuel regulating valve.

Oil firing in some respects is quite similar to gas firing. The fuel regulator throttles the oil delivery to meet the fuel needs. Since the fuel pressure is essentially constant no additional regulators for this purpose are included.

Oil- and pulverized-coal-fired furnaces have one feature in common which makes their control methods somewhat similar. Furnaces in which the operating range is

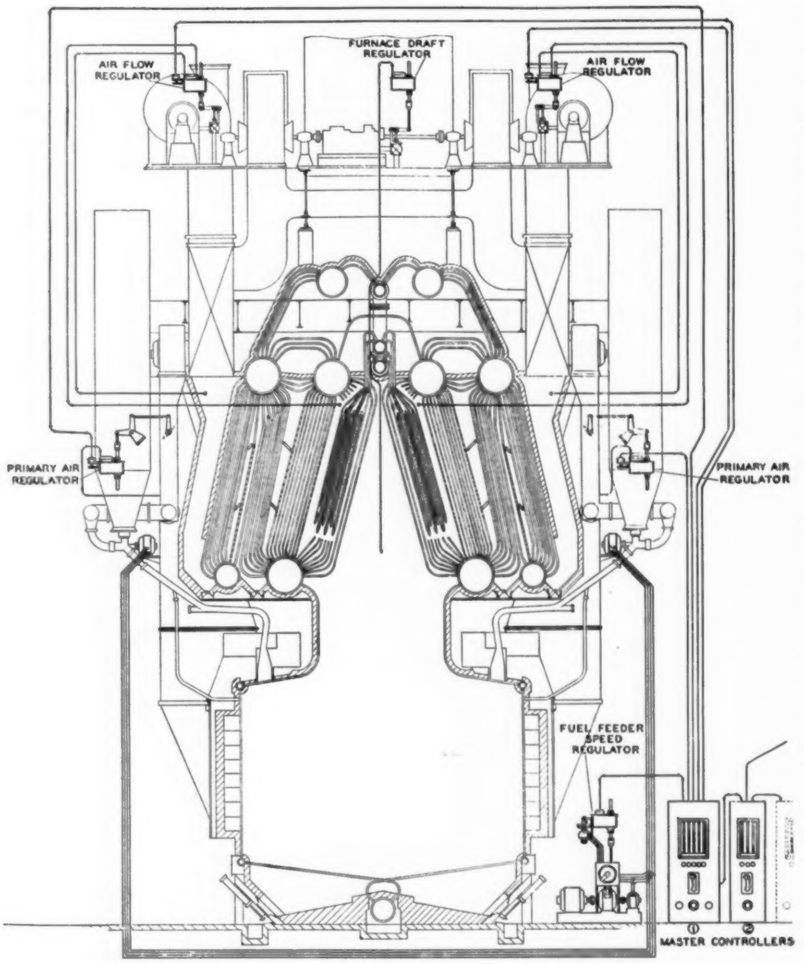


Fig. 5—Smoot control applied to a large boiler

quite wide, may find their demands beyond the suitable output of the burners. Oil burners do not regulate well beyond a three-to-one capacity. If the furnace demands are say six to one, it becomes necessary to drop out or pick up a burner when the steam demand has exceeded the operating range of those in service. This requirement introduces limiting devices on the fuel regulator.

The control for pulverized-coal-fired furnaces differs from oil-firing control in respect to one principal item. Although both fuels are burned in suspension, pulverized coal requires air as a means of conveying it to the furnace. This air, known as primary air, enters into combination with the fuel and consequently reduces the air to be furnished by the forced-draft fan directly to the furnace. Primary air may or may not have come initially from the forced-draft fan.

In a system consisting of a pulverizing mill, piping and a burner, the velocity of the air must be maintained or the fuel carried in suspension will settle in the conveying pipe. At or near the maximum designed rating for the system, one pound of air may be adequate to convey a pound of fuel, the volume of the air being sufficient to give the desired velocity. Assuming the total air flow unchanged at lower ratings, however, when the amount of fuel has been diminished, the ratio of air to fuel will be higher than three or four to one. As the amount of coal being thrown into the air stream in the mill causes one of the resistances to air flow, it follows that with the reduction in the coal quantity, air flow will increase. This aggravates an already undesirable condition, for stable burner operation is partly contingent upon not too great dilution of the fuel. To avoid this possibility, the air should be dampered to not less than that required to insure fuel pickup in the mill and to prevent fuel settling in the pipe and burner. The damper to accomplish this may be installed in the mill exhauster duct and as its position for suitable air flow for a specific boiler rating should be invariable, it can be operated by a mechanical device which will always take a definite position for each rating. However, it may not be possible to predict the desired setting of the damper beforehand. In that case, it is better to wait until installation of the mill and burner system has been completed, results obtained by manual adjustments and then to duplicate these by the combustion control damper operators.

As a final example of a control installation, reference is made to Fig. 5. Here we have a double-set boiler, pulverized fuel-fired, requiring feeder-speed regulation, primary-air regulation, furnace-draft regulation by forced-draft fan turbine-speed control and air-flow regulation by double induced-draft fan turbine-speed controllers. A station master panel sends forth the loading pressures required to the several boiler master panels as here indicated. These panels relay the loading to the several regulators of each boiler. By suitable levers and control hand wheels on the station panels the operators may control the entire station either manually or automatically, and by similar levers and handwheels on the individual boiler panels they may transfer any boiler to manual or automatic operation. They may also vary the loading pressure to any regulator at will thereby modifying the master loading and providing a variation of the fuel-air ratio, furnace draft or uptake draft.

In preparing this article the writer has at times been confronted with difficulties in attempting to portray the combustion control descriptions as applied to all furnaces. With the almost infinite number of furnace arrangements, boiler settings, boilers and combustion control systems it has been impossible to write with the thought of all conditions in mind. It is expected therefore that some of the general statements will be found not in agreement for some specific designs. If the general idea has been expressed as clearly as intended, it is expected that the reader will be able to modify it for any specific case.

A Short Course in Coal Utilization, principally for operating men, has been announced by the Department of Mining and Metallurgical Engineering of the University of Illinois, Urbana, Illinois. It is scheduled to cover three days, June 9 to 11 inclusive and details of the ground to be covered will be available about the middle of April.

Modernizing the Conners Creek Power Plant—V

Piping (Part 1)

By SABIN CROCKER

Engineer, The Detroit Edison Company

The four preceding articles concerned the buildings and canals, the turbine generators, the boilers, stokers and zoned air control, the plant operating cycle and heat balance. The present installment on piping is in two parts, that in this issue dealing with the welding procedure and that in the April issue covering the piping layout, piping supports materials and valves. The concluding article of the series in May will give an account of retubing the old condensers to serve larger units, deaeration of condensate, chlorination of circulating water, feedwater heaters, a tabulation of equipment and operating results.

As IN the case of numerous other items involved in the Conners Creek rebuilding project, a marked contrast has developed between the new and the old piping. While both typify advanced ideas of their day in design and construction methods, the new piping, by reason of improvements in materials and the development of welded joints, is deemed to afford a degree of reliability which warrants a considerable simplification in layout. Dual-supply systems, ring headers and the like, are no longer considered so essential as in the past. In addition to reconsidering what constitutes reasonable dependability against interruptions to service, the question of allowable fluid velocities and economical pressure drops was examined rather closely. The present trend toward treating each turbine with its corresponding boiler or boilers as a single unit rather than combining all turbines and boilers into an elaborate cross-connected system is manifest in the rebuilt plant, although not to the degree found in some plants of other companies. The overall result of these simplifications and improvements in construction methods has been a substantial reduction in the cost of piping per kilowatt of installed capacity.

Cast-steel pipe fittings were in vogue when old Conners Creek was designed and accordingly this material was adopted for the fittings and valve bodies of the steam and blowoff lines, although not for the boiler feed where semi-steel, the prototype of what is now known as high-strength gray iron, was used. The idea of taking the main-steam cross-over connections from enlarged manifolds through which steam turned the corners at a reduced velocity originated, in so far as this Company is concerned, at Conners Creek, and persisted in modified form through the construction of Marysville, Trenton Channel and Delray No. 3 power houses.

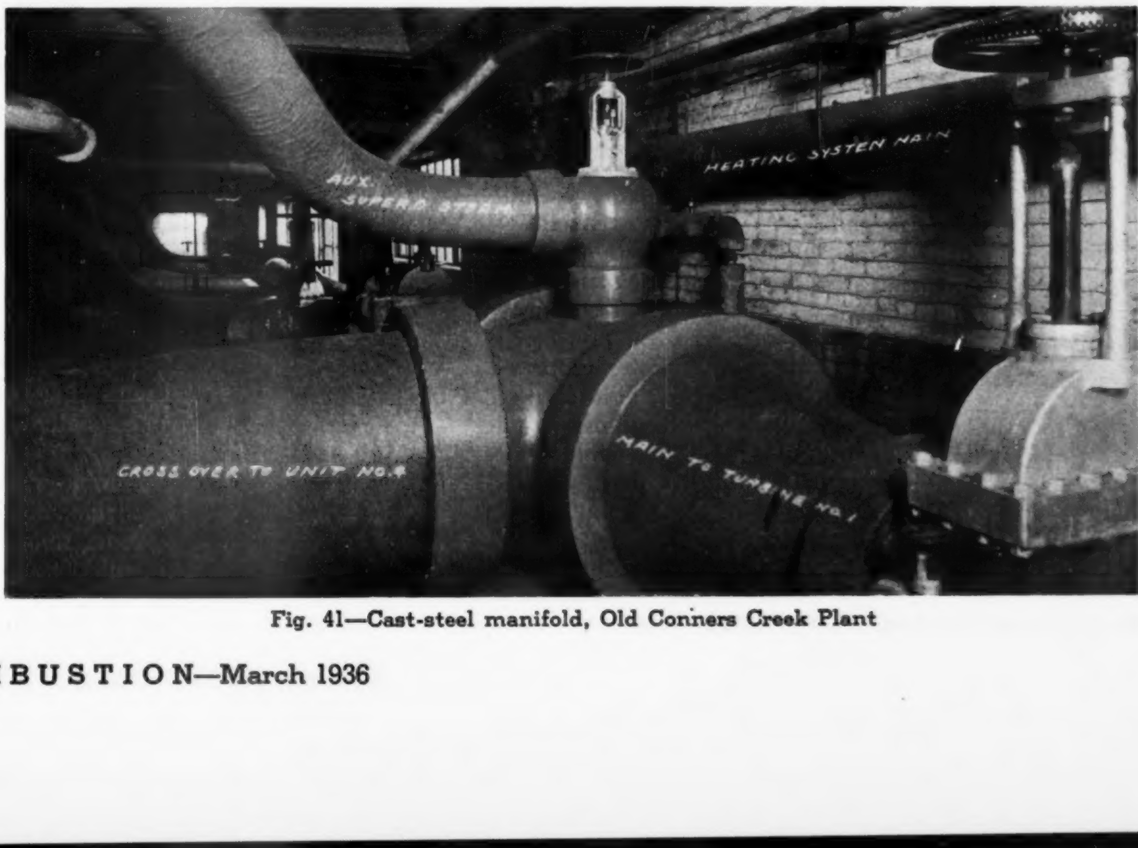


Fig. 41—Cast-steel manifold, Old Conners Creek Plant

A fitting of this type used to increase the size of a 14-in. OD steam line to the equivalent of a 28-in. OD line where a right-angled turn occurred is shown in Fig. 41. This arrangement, judged by present day standards, was not only clumsy and awkward but also introduced the hazard of keeping tight unnecessarily large joints. In later plants these fittings were redesigned and combined to eliminate the 28-in. joints and hold the maximum size of flanged connection down to about 16 in. In this development a single large manifold casting having an inside diameter of 22 to 30 in. took the place of one or more 28-in. tees with their adjacent straight or horned nozzles, thus keeping the size of the largest flanged connection down to that of the pipe line. This phase of the development reached its zenith at the Trenton Channel plant where cast-steel manifolds over thirteen feet long and weighing up to eight tons were used. A casting of this type, a tee with a side outlet, is illustrated in Fig. 42. The high cost of these manifolds, coupled with the difficulty of obtaining sound castings in such large sizes, led to a modification of the design at Delray No. 3 and to its ultimate abandonment in the rebuilding of Conners Creek when a switch was made to built-up welded manifolds such as shown in Fig. 43.

The adoption of welded joints in high-pressure high-temperature lines for the first time in the Company's plants was a forward step in keeping with present day developments in the art of welding which was taken after some ten years' experience with welding low-pressure lines. Decision to weld was made only after setting up rigid qualification tests for pipe welders, providing competent supervision supported by Arcronograph records, and conducting extensive tests to establish the satisfactory quality of the work. These steps are covered at length later in the article, along with an account of novel construction details built up through welding technique.

Welding

The decision to use welded pipe joints and fabricated manifolds in the high-pressure high-temperature lines of the rebuilt plant was reached through development work under less severe service conditions extending over a period of several years. About 1924 the Company began seal welding the backs of screwed flanges in exhaust and bleeder lines to insure having tight joints under vacuum, and erected a considerable amount of circulating-water piping using socket joints with fillet welds. During succeeding years the use of welding was extended to embrace butt-welded joints and fabricated fittings in miscellaneous lines under vacuum or low pressure. In 1928 the Company employed a contractor to lay a mile of 16-in. district-heating feeder line using butt-welded joints, and about the same time initiated welding of cross-country gas and 75-lb pressure gas-plant piping by its own construction force, in addition to carrying on a substantial amount of welding of district-heating service mains with its underground-lines crew. A considerable background of experience was obtained through these types of work, and a set of rigid qualification tests for welders developed which serves to establish the competence of each operator before he is allowed to weld pipe joints. The concurrent advance in the art of welding pipe joints elsewhere, including the development of covered electrodes for arc-welding, also tended to inspire greater confidence in this type of joint. The gradually acquired ability to make a good weld with the joint in a fixed position so that part of the work had to be done overhead was deemed to have reached an acceptable standard about this time. These facts, coupled with the trouble anticipated in keeping bolted joints steam tight at 850 F and the relatively high cost of vanstoned construction for high pressure offered great incentive to welding.

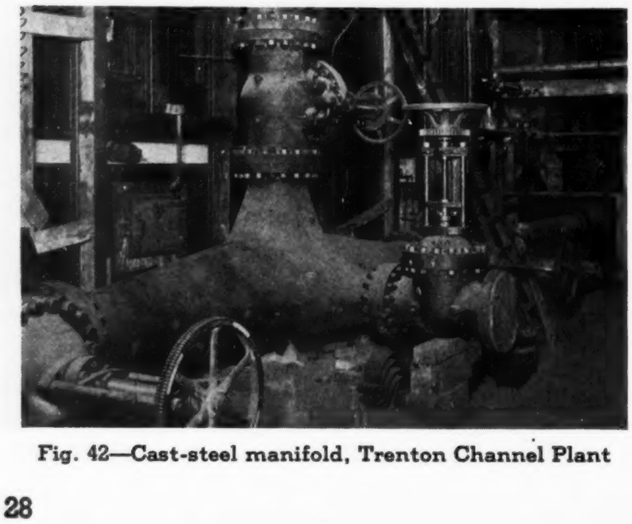
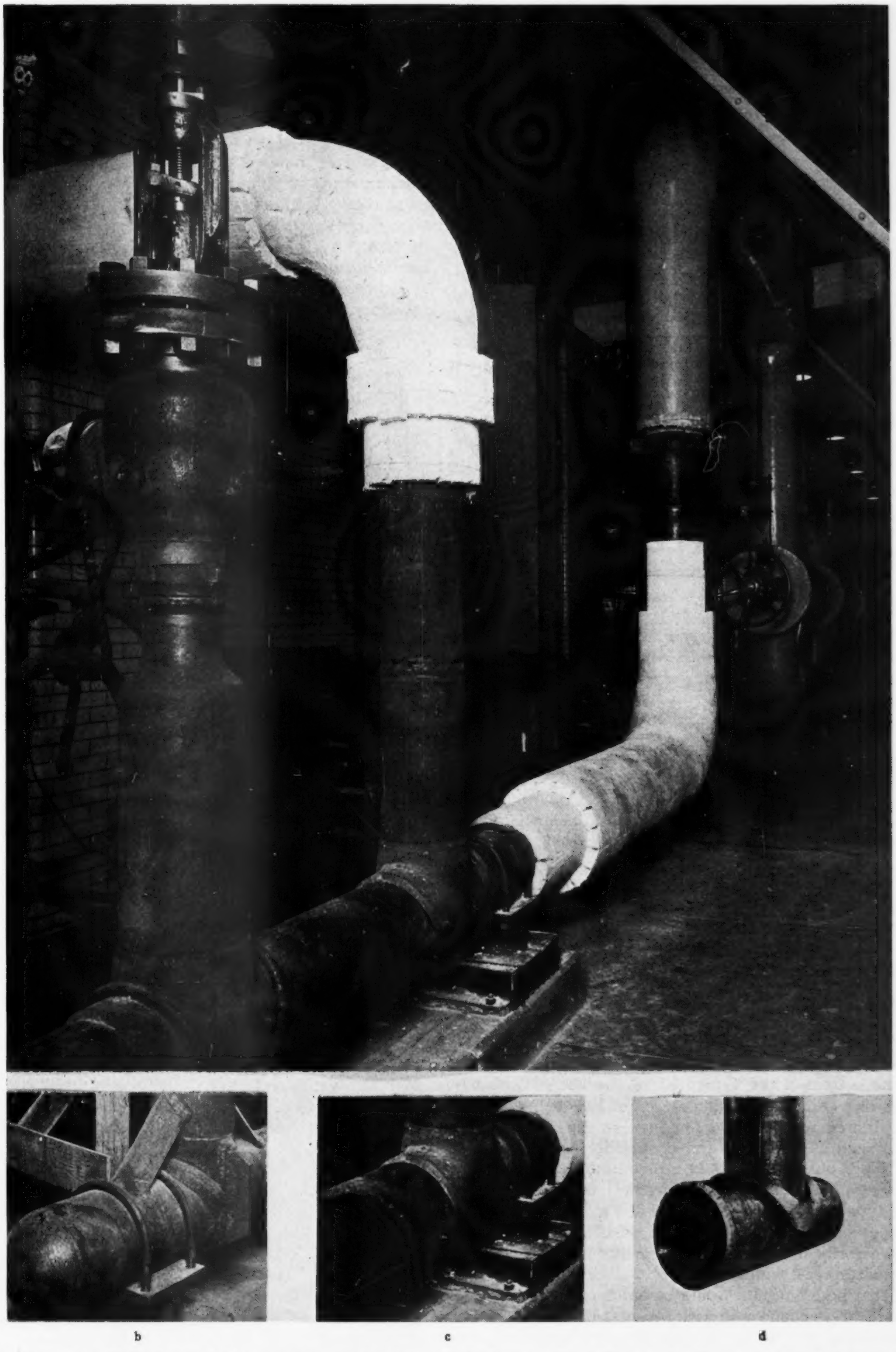


Fig. 42—Cast-steel manifold, Trenton Channel Plant

It was felt that for a high-temperature welded job to be reasonably complete, valve ends as well as pipe joints should be welded, using flanges only for bonnet joints and possibly at points of attachment to equipment. In order to eliminate end flanges on valves it became necessary to make pipe-to-casting welds in addition to the usual pipe-to-pipe welds. This was considered somewhat more difficult to do, especially with the alloy-steel valve bodies which seemed called for on account of the reduced section adjacent to the welding ends where the wall thickness is tapered to be just slightly more than that of the pipe. Then the question of creep at 850 F seemed important, particularly since not much was known about the tendency to creep in weld metal at the joints, whether pipe-to-pipe or pipe-to-casting; all of which pointed to the need for a careful laboratory investigation of the results obtained in making trial welds under field conditions with the actual materials contemplated. These items are discussed in some detail below.

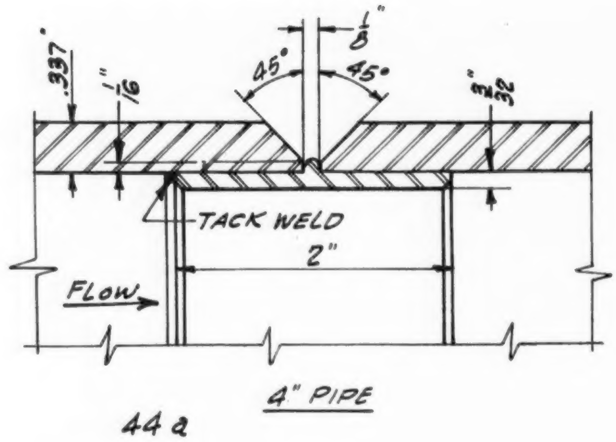
Welding Process

The pipe-welding technique built up by the Company's Construction Bureau is based on the use of the direct-current, metallic-arc process with coated electrodes. All welders employed on piping work are required to pass extensive qualification tests and are allowed to work on high-pressure lines only after having thoroughly demonstrated their skill and dependability on less exacting services. Extensive investigations have been made to determine the most satisfactory form of bevel, proper clearance, best composition and size of electrode, desirable number of beads, and the effect of such operations as cleaning and chipping, peening and stress relieving. The aim has been to develop a simple butt-weld which is sufficient in itself without the use of reinforcing straps or other supporting devices. Since little difficulty has been experienced in making

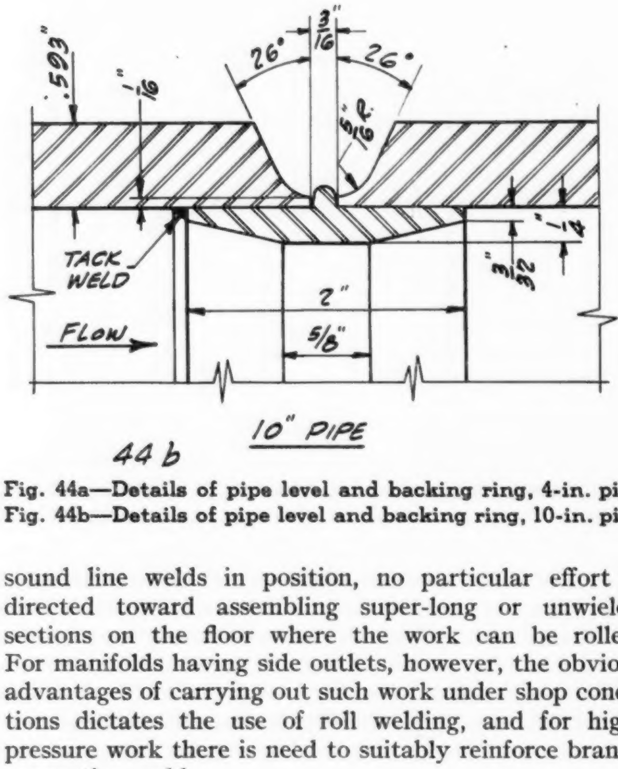


b c d

Fig. 43a—(top) Welded manifold in main steam header, rebuilt Conners Creek Plant; b—Gusset-plate reinforcement; c—Saddle-type reinforcment; d—Ring-type reinforcement



44 a



44 b

Fig. 44a—Details of pipe level and backing ring, 4-in. pipe
Fig. 44b—Details of pipe level and backing ring, 10-in. pipe

sound line welds in position, no particular effort is directed toward assembling super-long or unwieldy sections on the floor where the work can be rolled. For manifolds having side outlets, however, the obvious advantages of carrying out such work under shop conditions dictates the use of roll welding, and for high-pressure work there is need to suitably reinforce branch connection welds.

Backing Rings and Shape of Bevel

The desirability of avoiding weld spatter inside the pipe and at the same time of obtaining full penetration to the bottom of the V pointed to the use of backing-rings in medium and large-size pipes. A simple device was desired which would not involve expensive operations such as upsetting and counterboring the ends of the pipe, but which would still be sufficiently sturdy without unnecessarily restricting flow through the line. The type of backing rings shown in Fig. 44 was adopted for pipe sizes $2^1/_2$ in. and larger in the belief that it would satisfactorily meet these requirements for medium and large-size pipes, while for sizes 2 in. and smaller it was felt that better results would be obtained through using fillet welds in connection with sockets or external sleeves as shown in Fig. 45 (a, b, c and d).

The backing rings shown in Fig. 44 are a ready-made variety in the form of a split band, somewhat tapered at the edges, and having a central ridge which properly spaces the pipe ends and helps in aligning the pipe bores. It also provides a neucleus for fusing in with the first bead. All burrs are removed from the inside of the pipe-end before inserting a backing ring so as to obtain as snug a fit as possible. The gap between the ends of the split ring is closed with a single light bead and any weld spatter removed from the inside of the pipe. Backing rings which fail to have their ends close by more than $^3/_{16}$ in. are not used. For pipe sizes smaller than 6 in. the rings are of pressed steel with an intermittent ridge, while for sizes 6 in. and larger they are of forged steel with a continuous ridge.

Although simple in nature and relatively inexpensive to apply, these devices have proven eminently satisfactory both from an erection viewpoint and in service, so that the Company's engineers see no reason for considering the use of more elaborate and costly substitutes. In addition to their other advantages these backing rings have been found of assistance in aligning the pipe prior to tack welding.

For pipe walls up to $^1/_2$ in. thick the conventional 45-deg bevelled end shown in Fig. 44a is used. In the case of heavier walled pipes, however, it was felt that the double 45-deg bevel left too much material to be deposited during the welding operation and after some experimentation, it was decided to use the 26-deg U-type of bevel shown in Fig. 44b for pipe walls over $^1/_2$ in. thick.

Where welding-end valves were used in sizes $2^1/_2$ in. and larger, it was necessary to taper the wall thickness of the valve on the outside adjacent to the weld as shown in Fig. 43. In this way it was possible to let the thickness of the welding end approach that of the pipe, and at the same time have the bore of pipe and valve coincide.

Electrodes and Number of Beads

In the welding of thick-walled pipe by this process experience has indicated the advantage of depositing weld metal in a relatively large number of thin layers rather than attempting to fill up the V with fewer thick layers. The Company's rules require that there shall be not less than one bead or layer per $^1/_8$ in. of pipe wall thickness, and further that the size of electrode used shall be such as to permit depositing not less than two beads of weld metal. Only covered electrodes of approved brand are used, and welders are permitted to use only the brand or brands with which they have passed qualification tests. Some difference in technique is required for position welding where the pipe axis is

Fig. 45a—Socket-welding fittings, elbow and tee

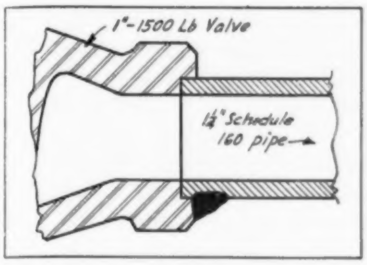


Fig. 45b—Detail of socket for welding-end valve

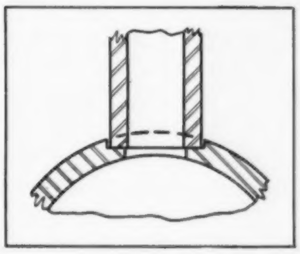


Fig. 45c—Detail of attachment of small pipes to large pipe

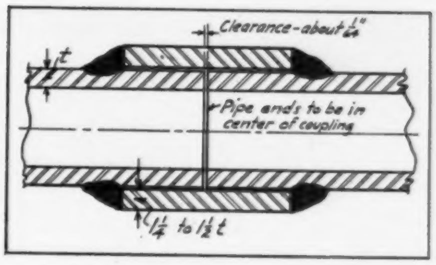


Fig. 45d—Detail of welded coupling

vertical rather than horizontal. For instance with horizontal pipes having $^1/_2$ to $^3/_4$ in. wall some six to twelve layers are desirable with the beads laid in waves to and fro across the V to form each layer. With a vertical pipe of corresponding wall the same number of layers would be used, but in this case there might be fifteen to twenty individual beads laid in the V as separate rings. The use of a multiplicity of layers aids in securing a sound weld both through minimizing the tendency for porosity and through a refining of the grain structure afforded by the heat of each successive layer. Cross-sections of welds made with the pipe axis in horizontal position are shown in Figs. 46a and 46b. Both specimens were taken from the top portion of the joint. The upper macrograph is representative of the method of welding used during the early stages of the welding investigation while the lower macrograph is representative of welds made at the present time.

Particularly with coated-electrode work there is necessity for thoroughly cleaning each successive bead in order to remove the coating of slag. Following this operation, which ordinarily is done by hand with a wire brush and a light ball-peen hammer, it is essential that the bead be smoothed up with a pneumatic chipping tool and any unfused portions cut out to sound metal. While the chipping operation does give some peening effect, it is carried on purely as a means of smoothing and leveling the surface of the weld and to eliminate unfused areas rather than for any value it may have for stress-relieving or grain-refining purposes. The final layer is chipped smooth and peened lightly to give a finished appearance resembling that produced by hammering or knurling.

Because of the predominance of the personal equation in welding, precautions are taken to avoid fatigue of the welder in carrying on Class A work. In this connection it has been found advisable to have all chipping and cleaning done by a helper, principally on account of the arm strain produced in using a pneumatic chisel.

Stress Relieving

In view of the prevalent feeling that stress relief is beneficial to electric fusion welds, experiments were undertaken to find out how this could be done to best advantage and in what way the treatment improved the weld. The chief purpose in stress relieving a weld intended for use at 850 F or higher temperatures is to reduce any locked-in stresses before placing the line in service, thus minimizing the danger of starting cracks or opening up possible flaws in or adjacent to the weld. If it were not for the need of getting the weld through this rather ticklish initial period of warming up to the line and placing it in use, there would not be so much occasion for the stress-relieving operation for lines working at 850 F since the operating temperature would materially reduce the magnitude of such stresses if given enough time. In the case of boiler-feed lines and other high-presure lines operating at temperatures of 400 F and below, there is little possibility of this self-annealing effect. Consequently, the desirability of stress relieving such joints is even more apparent.

The need was sensed for developing some portable device for stress relieving which could be operated under automatic temperature control, thus precluding the possibility of damaging the work through overheating. With the ordinary gas- or oil-fired refractory ring there is not only a possibility of overheating the weld and adjacent pipe to the point of burning the metal or otherwise damaging the grain structure, but the use of a too copiously applied source of heat at the point of attachment to a valve body also introduces the hazard of warping the valve mechanism. For these reasons experiments were undertaken to find out how stress relieving could be done to best advantage electrically with the temperature under close control.

In the temperature range at which it is desired to stress relieve, namely, 1100 to 1200 F, induction heating with ordinary 60-cycle alternating current is an entirely practicable means of developing sufficient heat directly in the weld metal and adjacent pipe wall. Experiments were undertaken, therefore, to find out how 60-cycle current could be used to best advantage, how this treatment affected the weld, and whether there was a tendency to overheat valve parts when adjacent to a weld undergoing stress relief.

Through this investigation the electric induction heating device shown in Fig. 47 was developed. The winding itself consists of several turns of an electrical conductor clamped around the pipe directly over the weld, from which it is separated by a layer of heat insulation. The insulation serves both to hold the heat in the weld and adjacent pipe, and to keep the self-cooling conductor turns from short-circuiting and overheating.

The stress-relieving collar is in the nature of a transformer in which the conductor turns comprise the primary circuit, and the weld and adjacent pipe wall a one-turn secondary, short-circuited on itself. When alternating current passes through the primary it induces a much heavier low-voltage current in the one-turn secondary, thus developing heat where it is actually wanted. By providing an adjustable-voltage current supply to the primary it is possible to bring the joint up to temperature quickly and then to cut down the current to hold any desired temperature for the required time; after which the current can be gradually

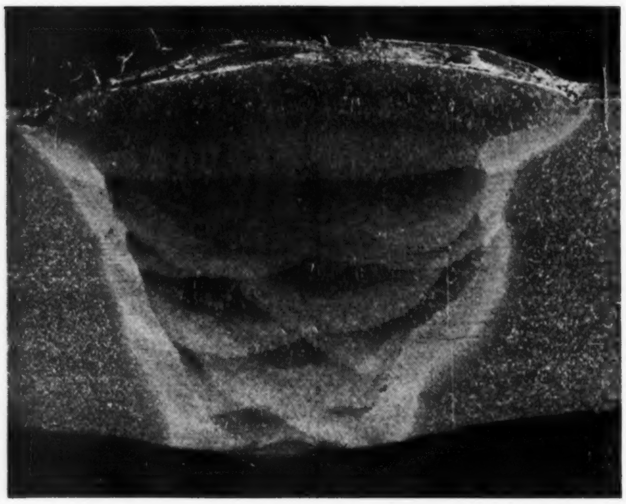


Fig. 46a—Macrograph section of top portion of horizontal qualification-test weld made during investigation of welding. Magnification $2^1/_2$ times

decreased to give as slow cooling as may be wanted. A thermocouple tacked to the weld serves to indicate temperature and to actuate an automatic temperature controller. By this controller the temperature at any one point of the weld is maintained within 20 deg F of that desired.

The maximum point-to-point variation of temperature around the weld resulting from variations in surface radiation, etc., has been found to be approximately 50 deg F for pipe diameters of 12 to 16 in., with less variation for smaller pipes. Beyond the heated area embracing the weld the temperature tapers off, of course, due to conduction through the pipe wall and radiation from the part outside the collar. The uniformity of temperature in the weld is so close and the tapering off outside sufficiently gradual to preclude serious strains from unequal heating and cooling.

With standard length valves in the sizes which are stress relieved, namely, $2^1/_2$ in. and larger, the distance between the welding-end and the seats is sufficient to avoid overheating and warping these parts. Actual measurements taken while stress relieving the joint between a pipe and a 6-in. 600-lb welding-end valve showed that the temperature of the seats would not exceed 500 F with a temperature at the joint above 1200 F. Experience in service with a large number of valves, whose welding ends have been stress relieved, has yet to show a single instance of damage to the seating parts from this treatment.

The adjustable-voltage current supply is obtained from a multiple-tap transformer which provides 25 voltage steps from minimum to maximum. In order to make the auxiliary equipment readily available to the location where welding is being done, the transformer, tap-changer, switches and automatic control equipment are all mounted together on a hand truck and equipped with long primary and secondary leads. This particular tap-changing transformer can be operated from any 230-volt, 60-cycle circuit of sufficient capacity, but there is no inherent reason why a similar transformer cannot be operated from almost any alternating-current power circuit of proper size.

The present equipment has been used so far to stress relieve welds in pipes varying in diameter from $2^1/_2$ in. to 16 in., the different pipe sizes being provided for by having several windings such as that shown in Fig. 47, each of which is suitable for use on at least two pipe sizes. The collars are so compact that they can be used wherever there is sufficient clearance around the pipe to do a satisfactory welding job.

The purpose of stress relieving a weld in thick-walled material, as the Company's engineers see it, is twofold: First, to heat the affected portions of the structure to a temperature sufficiently high to allow any locked-in stresses set up by the welding operation to relieve themselves through creep; Second, to take advantage of the "drawing" or "tempering" action existing at 1100 to 1200 F commonly used in the heat treating of alloy-steel castings. This draw has been found to increase the ductility of electrically deposited weld metal as much as 50 per cent in some instances, and to improve the impact strength in the order of 10 to 15 per cent. In addition, it probably has a favorable effect on the fatigue strength. The improvement in these properties obtained by the tempering process is attributed to an equalization of the hardness characteristics of material throughout the weld. In a metallurgical sense this improvement is obtained through converting the martensite and troostite structures, produced in the rapid cooling of weld metal from the liquid state, to sorbite. In establishing the stress-relieving temperature at 1100 to 1200 F, the fact that the valve-body material was drawn at 1200 F was an important consideration since higher temperatures would have changed the physical properties of the cast material.

A commonly used rule for stress relieving welds is to hold the material within the temperature range of 110 to 1200 F for a period of one hour per inch of wall thickness. It is believed further that reasonably slow cooling to about 600 F, requiring one to three hours time, is beneficial. Cooling of this sort is readily obtained with the electric-induction-collar annealer, since the current can be tapered off as gradually as may be desired.

The electrical energy required for stress relieving varies with the size of the pipe, but is low in any case. For example, stress relieving a weld in a $2^1/_2$-in. pipe requires about 3 kw hr; in an 8-in. pipe, 13 kw hr; and in a 16-in. pipe, 22 kw hr. While the cost of electricity required to stress relieve welded pipe joints is insignificant, labor cost plus carrying charges on the investment in equipment may represent a considerable item. The whole amount involved, however, represents but a small addition to the cost of high-pressure piping.

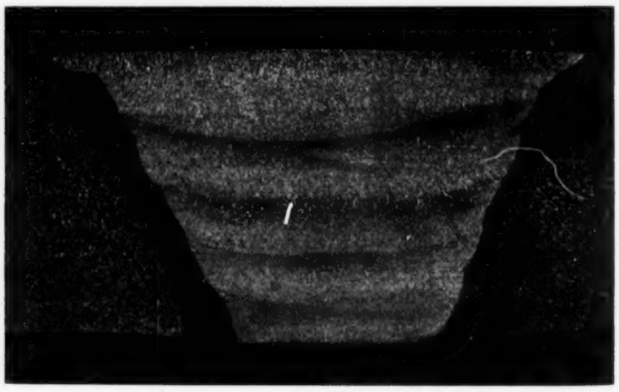


Fig. 46b—Macrograph section of present type of weld, top portion of horizontal qualification-test weld. Magnification $2^1/_2$ times

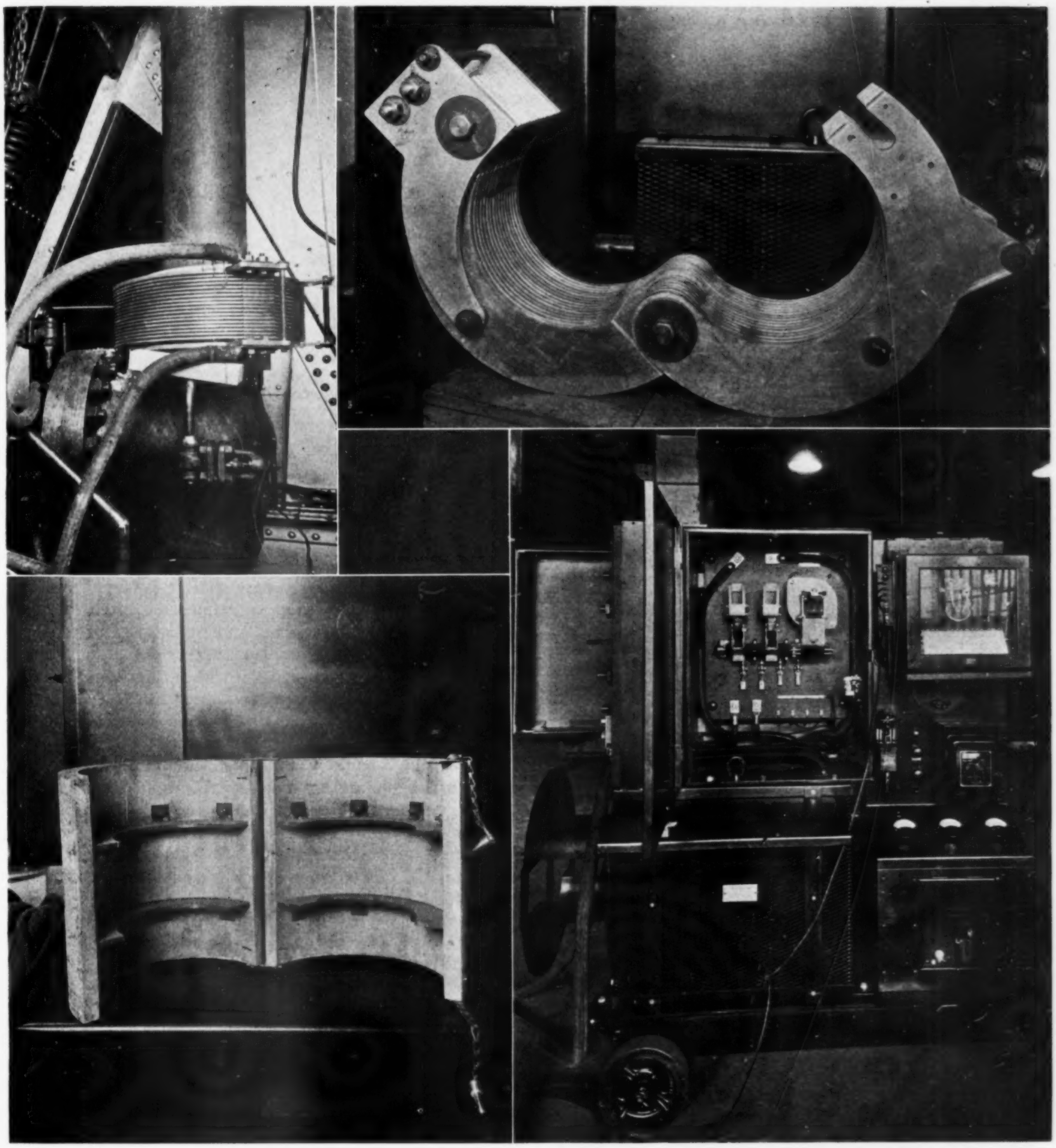


Fig. 47—(upper right), Stress-relieving collar; (upper left), 10-in. main superheated steam line valve with stress-relieving collar on welded joint; (lower left), insulating sleeve; (lower right), transformer and control for stress relieving pipe welds

Each welder working on high-pressure power piping is required to pass qualification tests which resemble in general those specified in the American Standard Code for Pressure Piping, the principal difference being a larger number of test coupons on the original qualification, and somewhat more rigorous requirements with respect to tensile strength and elongation. Periodic requalification tests for a welder who has once qualified and been engaged on pipe-joint welding need not be so extensive as the original qualification.

Having developed a welding personnel that could consistently produce welds of satisfactory quality under test conditions simulating field welding, the Company's engineers still wished assurance that the joints made in the field would be consistently sound. It was felt that something beyond visual inspection and periodic examination of sample welds was required to insure uniform quality. That no serious question has come up regarding the quality of a high-pressure weld is attributed to the following factors: (1) the unusual skill of the operators; (2) the pains taken in executing and supervising all phases of the work; (3) the attention given to developing

adequate design details; (4) the use of the Arcronograph.

The Arcronograph

Recognizing the importance of the human factor in welding and the great dependence placed on the steady reliability of the operator, some adequate method of quality control was sought, either through a non-destructive examination of each completed weld if such proved practicable, or through some system of supervision which would give a continuous record of the conditions under which weld metal was deposited.

X-ray and gamma-ray methods were considered and discarded on the grounds of being unsuited to field work and inapplicable to branch-connection welds. A magnetic method of examination was experimented with and found unreliable in that it failed to detect certain serious flaws purposely produced in a specimen intended for examination. About this time a graphical recording device[1] came to the attention of the Company's engineers, and after some investigation was adopted as offering the greatest promise of a satisfactory means of controlling weld quality.

This device is an electrical recording instrument which employs a three-element vacuum tube to take account of the ratio of arcing time to short-circuiting time in the process of depositing each globule of weld metal. Since this ratio should be essentially constant for a given size and type of electrode, the graphical record serves to show how consistently the operator has performed in laying on each bead. Satisfactory limits for the graphical record produced when using any given electrode are set initially through observing the range of chart values obtained while doing test work which is known to be satisfactory. If in actual welding the graph swings outside the predetermined limits, that portion of the work is then subject to suspicion and due for examination. Any flaws in the bead thus become apparent as the work proceeds and can be chipped out or otherwise corrected while the bead is still exposed without having to wait for an X-ray or other examination of the completed weld. Welders ordinarily check the record as they finish each bead. The fact that the welder works under the constant supervision of a graphical record and cannot bury his mistakes is considered one of the principal advantages of the instrument. A photograph

[1] "Evolution of the Arcronograph," by Bela Ronay, *Journal of the American Society of Naval Engineers,* August 1934.

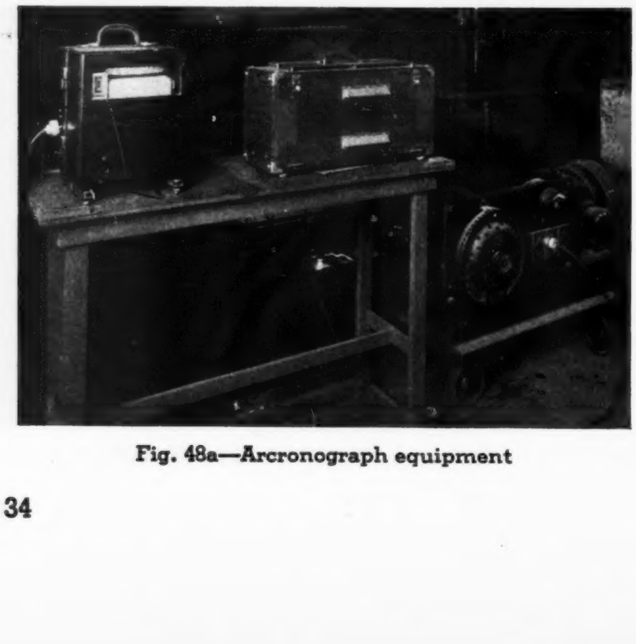


Fig. 48a—Arcronograph equipment

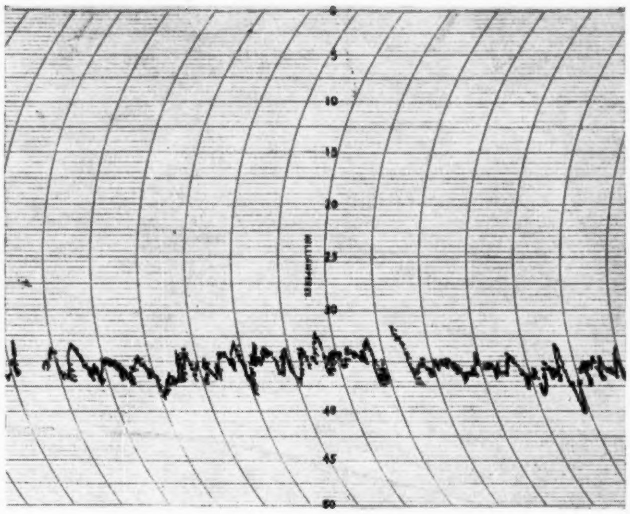


Fig. 48b—Typical Arcronograph chart

of a portable outfit of this kind and a typical chart are shown in Figs. 48a and 48b.

All piping systems containing welded joints are, with very minor exceptions, given a hydrostatic test. The test pressure specified is twice the normal working pressure, except that in no case shall it be less than 50 lb per sq in. nor more than $1^1/_2$ times the rated steam-service pressure of the valves and fittings. During the hydrostatic test the material on both sides of the weld and close to it is hammered with blows hard enough to jar the weld without denting the material. According to Company instructions small pin-hole leaks shown by the hydrostatic test may be repaired by chipping out and rewelding, while welds that leak badly must be cut from the line and replaced with a welded-in section. Because of the care taken in welding high-pressure joints no leaks of any kind have occurred in butt-welded joints either on hydrostatic test or in service. A few pin-hole leaks have occurred, however, in some threaded and seal-welded instrument and drain connections used in the first sections where pads were built up with bare wire rather than coated electrodes to facilitate threading.

Details for Welding

The adoption of welded construction called for the development of many new design details adapted to taking full advantage of this new method. In some cases the final solution was not at once evident and was evolved through cut-and-try procedure or through using a preliminary design for the first unit, which was then improved for succeeding units.

The use of built-up manifolds in place of large steel castings has already been mentioned. Welded manifolds are fabricated from seamless pipe with the branch outlets cut and fitted as accurately as possible and reinforced according to the Boiler Code rules for nozzle connections. The main-steam manifolds used in connection with Units 8 and 9 were made in a commercial piping fabricator's shop and reinforced as shown in Fig. 43b with strut angles, wing plates and a built-up welding V. The assembly was stress relieved complete in a large furnace. The design used for Unit 10 was fabricated by the Company's own welders, also according to Boiler Code rules, but using saddle reinforcements which were slipped over the initial fish-mouth welds

as shown in Fig. 43c and then attached by fillet welding to both manifold and branch. The manifold and branches were arranged so that all welding could be done under the equivalent of shop conditions. The completed assembly was stress relieved as a unit in a furnace. This method of stress relieving was used to insure uniform and thorough heating of welds and reinforcement. The ring type of reinforcement shown in Fig. 43d will be tried for the third section of the rebuilding project.

Installation of Flow Nozzles

How to install the flow nozzles was one of the interesting problems in changing over to all-welded construction. The conventional place for a flow nozzle has been at a flanged joint where the flared rim of the nozzle could be clamped between the flanges. The welding of a flow nozzle into the line involved working out a design which would eliminate distortion of the carefully calibrated nozzle, or at least reduce it to satisfactory limits.

With this end in view a design was evolved and a trial job of welding done with an actual flow nozzle. Careful measurements were taken with micrometers and the distortion found to be somewhat more than was deemed permissible. The design was then altered to that shown in Fig. 49 and another trial made, this time with satisfactory results. The change consisted in providing additional radial clearance between the inside of the pipe and the cylindrical member "Y" to allow for the contraction of the pipe at the weld. The flexibility of the member Y is sufficient to avoid distortion of the nozzle proper during the welding and stress-relieving operations.

Small Joints

In working out an all-welded high-pressure piping system, equally satisfactory details were desired for small pipes as for large. It was felt, however, that with the thinner wall sections of small pipes ($^1/_2$ to 2 in. diam) there was no occasion to stress relieve the welds. A variety of cases existed, each requiring somewhat special treatment. Among these were pipe-to-pipe line welds, pipe-to-fitting or pipe-to-valve welds, and the attachment of small pipes to large pipes or valve bodies for instrument connections, by-passes, drips, etc. Practically all of these started out as threaded connections seal-welded for tightness, of the type shown in Fig. 49; but they shortly evolved into full-strength socket welds. Typical connections of this sort are shown in Fig. 50.

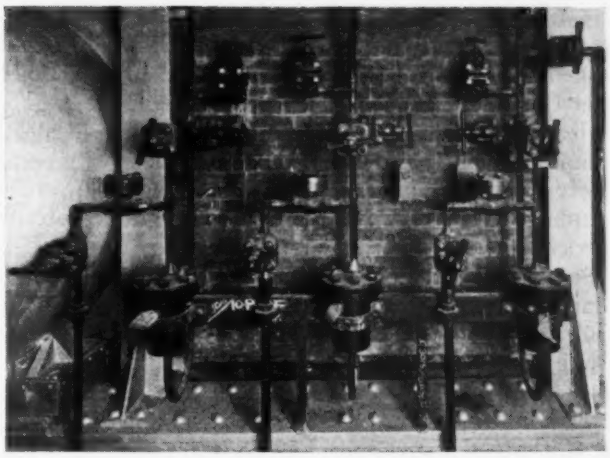


Fig. 50—Trap installation showing socket-welding fittings and valves as typical for small joints

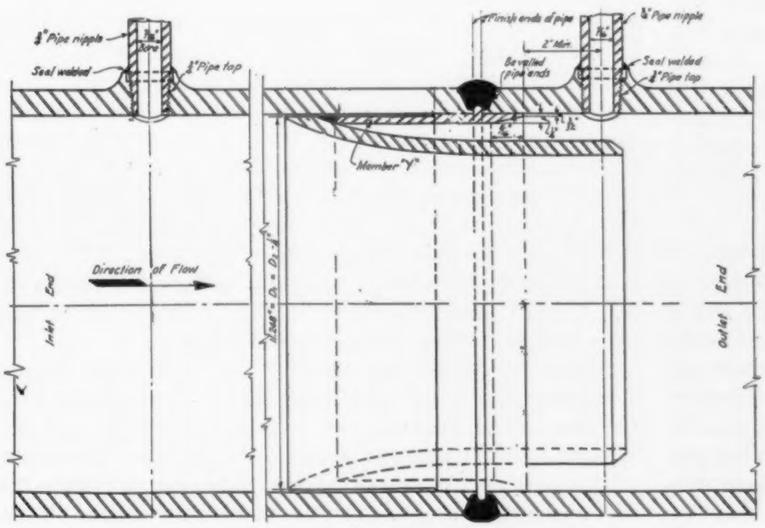


Fig. 49—Detail of welded flow nozzle

The change-over came about through a series of practical demonstrations of the efficacy of socket-welded construction for small lines. Using one or two beads it was possible to make fillet welds as strong or stronger than the parts joined. The high efficiency of small socket-welded joints is due in part to the fact that the weld is made on a substantially larger circle than if the same parts were joined by a butt weld, thus providing considerably more weld metal to take a given load. The different types of socket connections are explained below in more detail.

The welded-sleeve coupling for small pipes shown in Fig. 45d is a logical development from the threaded coupling, and serves essentially the same purpose. It also makes feasible the omission of most of the unions commonly used with threaded construction, as evidenced by the absence of unions in the high-pressure piping of Fig. 50. All unions shown in this view are on the low-pressure side of the traps. With welded construction most of the connections are merely welded up solid in the knowledge that, if the line must be taken apart, it can be cut in two with a hacksaw or torch and remade with a welded coupling. The necessity for making two fillet welds with such sleeves in place of a single butt weld is, of course, obvious, but this kind of work goes together fast and the ability to avoid weld spatter is worth the extra weld.

For high joint efficiency with a fillet weld the wall thickness of the sleeve or socket should be somewhat greater than that of the inserted pipe. The reason for this is to obtain sufficient length for both legs of the fillet, as is readily apparent on examination of the socket and sleeve details shown in Fig. 45. Taking this into consideration as well as the fact that good welding is facilitated when the parts joined are of somewhere near equal thickness, it works out that the coupling should be about $1^1/_4$ to $1^1/_2$ times as thick as the pipe.

For the high-pressure services at the Conners

Creek plant the couplings were made from double-extra-strong pipe two nominal sizes larger than the line, and drilled out to give about $^1/_{32}$-in. clearance on the diameter over the nominal outside diameter of the line. A gap of at least $^1/_{64}$ in. is left between the pipe ends inside the coupling to allow for differential movement of pipe and sleeve during welding. Bored-out forged-steel screwed couplings have been found suitable for lower-pressure service.

Small valves such as those shown in Fig. 50 were adapted conveniently from threaded valve designs by drilling the ends for sockets instead of tapping with the usual threads. The outside of the hexagonal ends were turned down as shown in Fig. 45b to give a spigot having a thickness at its outer end about $1^1/_4$ to $1^1/_2$ times that of the pipe. Experience has shown that the seating parts of such valves are not heated sufficiently during welding to cause distortion or warping, and the results have been highly satisfactory.

A large number of socket-welding tees and elbows were used in the small-size high-pressure drip and instrument lines, as illustrated by the trap installation of Fig. 50. A tee and an elbow of this type are shown in Fig. 45a. The relatively shallow sockets were found advantageous rather than otherwise, and fully accomplished the purpose of preventing weld spatter entering the pipe.

Attachment of Small Pipes to Large Pipes or Castings

Past practice in the case of valve by-passes, cast-manifold drips and the like has been to provide integrally-cast pads which were drilled and tapped if required for the attachment of threaded pipes, usually ranging in size from $^3/_4$ in. to $1^1/_2$ in. Where small pipes of this sort were to be attached to large wrought pipes it formerly was customary to build up welded pads to supplement the pipe wall thickness, and then drill and tap the combined structure.

A transition stage was passed through in switching to all-welded construction. The intermediate step consisted in drilling and tapping the boss deep enough to have the threaded end of the small pipe entirely countersunk into the pad, and seal welding between the boss and the pipe wall just beyond the threads, as shown in connection with the flow nozzle of Fig. 49. The next and probably ultimate step was to omit both the threads and the built-up welded boss on wrought pipe and merely drill, spot face and slightly counterbore the wall to provide a socket into which the small pipe was inserted and fillet welded. A typical detail of this method of attachment is shown in Fig. 45c. A similar procedure is now followed in the attachment of by-passes to valve body castings, where the pads are drilled and then counterbored to make a socket for fillet welding.

Comment on Welding

The results obtained through the adoption of welded construction for high-pressure, high-temperature piping have been most encouraging. The incentive for using welding is decidedly greater here than with low-pressure piping. The problem has been interesting in that the field is relatively new and each step in the development has led to another. Flanged joints, and for that matter screwed joints as well, have been eliminated from the 850 F piping except for valve bonnets and where the steam lines are attached to equipment. In the case of the 60,000-kw unit, connections to superheater outlets and to the oil-operated stop valve are both to be welded.

The application of welding to boiler-feed lines was not so extensive as with superheated-steam lines in the first sections of the rebuilt plant since the temperature is not high enough to cause creep in bolted flanges, and the close grouping together of numerous valves and fittings at by-passes and crossovers does not lend itself so readily to welded construction. Welding was used, however, where there was any considerable run of pipe between valve nests. In the section now under construction, all line joints including pipe-to-valve joints in the boiler-feed header will be welded. It has also been found possible to eliminate some twenty flanged joints in the boiler-feed valve nest at each boiler.

Waterside Station Goes to High Pressure

To care for a heavily increased demand for alternating current service in the mid-town section of Manhattan, the New York Edison Company, Inc., will immediately start construction in the modernization of its Waterside generating station. The initial project involves the installation of two high-pressure boilers, each of 500,000 lb per hr capacity, generating steam at 1325-lb pressure, 900 F temperature and supplying a 50,000-kw 60-cycle turbine-generator which will exhaust at 200 lb to existing low-pressure turbines in the station where it will provide an additional 65,000 kw.

Waterside generating station consists of two adjacent plants, Nos. 1 and 2, in which there are installed a total of 146 boilers having an aggregate output of 5,256,000 lb of steam per hour and 19 turbine-generators of 376,200-kw total capacity. This equipment was installed at various times between 1900 and 1924. The present high-pressure units are to go in Waterside No. 2 which will be provided with a new stack 450 ft high to discharge the stack gases at a level above the neighboring buildings. A system will also be installed for cleaning the gases. Thirty-six of the existing boilers and three of the turbine-generators will be retired at present.

The new high-pressure boilers will be of the CE sectional-header type having a low tube bank, directly above which are an Elesco superheater and continuous fin-tube economizer. Each will be provided with an air heater of the vertical-shaft Ljungstrom regenerative type. The boilers will be designed for 1400-lb pressure. Each will be served by two Raymond bowl mills and will be fired by tangential burners located at all four corners of the furnace which will be of the slagging type.

The turbine will be a 50,000-kw 3600 rpm Westinghouse machine of the two-cylinder reaction type taking steam at 1200 lb, 900 F and exhausting at 200-lb gage. Flexibly coupled to it will be a 3290-kw feed-heating turbine operating between 200-lb and 5-lb gage and bleeding non-automatically at 60-lb gage at full load. The generator will be hydrogen cooled and rated at 58,825 kva, 85 per cent power factor. It is the largest unit of this type and speed that has been sold to date.

Frank W. Smith, president of the New York Edison Company in a recent statement said: "We estimate that the rate of fuel consumption will be reduced to approximately half that now prevailing in the station. By reason of this new installation we expect to be able to reduce the fuel consumption of our electric system by about 100,000 tons a year."

Estimating Grindability of Coal

By H. F. YANCEY, U. S. Bureau of Mines
and M. R. GEER, Univ. of Washington

A brief abstract of a paper presented at the recent Annual Meeting of the A.I.M.M.E. giving results of comparative studies of grindability with the ball-mill method, the Hardgrove-machine and the C.I.T. roll-test. Inasmuch as coals are mixtures of components, each requiring different amounts of energy to grind, relative grindability results are accurate only if equal proportions of these components are ground to size suitable for use as pulverized fuel. This is accomplished only by the ball-mill procedure of testing as developed by the Bureau of Mines. The investigation was carried on under a cooperative agreement between the Northwest Experiment Station, U. S. Bureau of Mines, and the College of Mines, University of Washington, Seattle.

IN the ball-mill method, the relative amounts of energy necessary to grind coals to the same fineness are determined by the number of revolutions of the mill required to reduce 80 per cent of the feed (500 grams of 10 to 200-mesh coal) fine enough to pass a 200-mesh screen. This is a somewhat finer size than that commonly used for pulverized-coal firing. The finished product is removed in increments of 10 per cent by stopping the mill and screening out the undersize at the end of each cycle. This prevents overgrinding, maintains a more constant size distribution in the subsieve material and simulates the continuous removal practiced industrially.

In the Hardgrove-machine method, 50 grams of coal, sized between 14- and 28-mesh (Tyler) sieves, is ground in a special ring-and-ball machine for 60 revolutions. The resulting product, in which the amount of new surface is estimated from a screen analysis, is considerably coarser than a pulverized fuel.

The difference in the principles by which these two methods measure grindability is of particular importance. The ball-mill method is the only one so far proposed in which the relative amount of work required to grind coal to pulverized-fuel size is determined. By all other methods an equal amount of work is performed on each sample and the relative grindability obtained by estimating the new surface produced. Such procedures, although they may be reproducible, are subject to the limitation that by far the greater amount of surface is concentrated in the subsieve sizes; that is, the sizes that are finer than the finest sieves available. The approximation of surface in subsieve coal is an exacting and time-consuming task. Consequently, methods specifying a constant amount of work apply the same assumed mean size to the subsieve material from any and all coals. In order to test the validity of this assumed constant mean-size value, and to determine the effectiveness of stage removal in the ball-mill method, a study was made of the subsieve material obtained by testing three coals by both methods.

The coals selected for these tests covered a wide range in grindability, as is shown in Table I. Coal 1, from the Pocahontas No. 3 bed in West Virginia, is very easy to grind; coal 3, from the No. 6 bed in Illinois, is moderately difficult to grind, and coal 5, a Pennsylvania anthracite, is very hard to grind.

TABLE I

GRINDABILITIES OF THREE COALS BY BALL-MILL AND HARDGROVE-MACHINE METHODS

Coal No.	Actual		Relative	
	Ball Mill, Revolutions	Hardgrove, Per Cent	Ball Mill	Hardgrove
1	595	100.5	100	100
3	1166	60.1	51	60
5	1939	36.6	31	36

Comparison of Subsieve Sizes

Table II shows the results of the particle-size determinations on the portion of the subsieve coal that passes 400 mesh. The last two columns of the table show the average particle sizes of the total subsieve material. Two important conclusions may be drawn from these figures: First, in spite of the greater range in particle sizes occasioned by use of the 200-mesh sieve, the alternate grinding and screening of the ball-mill method produces subsieve material with only half the variation in average particle sizes of that produced in the Hardgrove method; and second, the average particle size is related to the grinding characteristics of the coal.

TABLE II

AVERAGE PARTICLE SIZE OF SUBSIEVE MATERIAL OBTAINED FROM GRINDABILITY TESTS

	Microns			
	Through 400-Mesh		Through 200-Mesh	Through 325-Mesh
Coal No.	Ball Mill	Hardgrove	Ball Mill	Hardgrove
1	29	24	54	29
3	26	28	57	32
5	31	34	58	37

Effect of Selective Grinding

Grindability is a composite property, dependent on a group of specific properties such as cleavage, fracture, tenacity, hardness and elasticity, which vary with the change in rank of coal, between coals of the same rank, and even between components of an individual coal. The variation of these properties between the components of many coals causes them to grind as heterogeneous mixtures of hard and soft material.

Several investigators of the problems encountered in grinding have referred to the differential action of grind-

ing machines if the feed consists of materials varying in grindability. If hard and soft materials are ground in the same operation the type of mill used determines to a great extent the relative reduction in size of each material. Some types give nearly the same reduction in size of hard and soft components; others show a marked differential grinding action. The degree to which such action takes place may be termed the selectivity of the mill in question. The nature and quantity of the components present in the feed determines the extent to which a given mill may selectively grind the less resistant portions. Selectivity influences the accuracy or correctness of a grindability procedure even though it does not influence the other prime requisite—its precision or reproducibility.

For a given coal, differences in ash contents of products obtained in grinding are undoubtedly due to differences in the relative grindability of the components with which the ash is associated. If the ash contents of all the cycle products or size fractions were equal, the sample might be assumed to have uniform grindability.

The work with mixtures of hard and soft coals has demonstrated that both methods use mills that grind selectively. The advantage of the ball-mill method in this respect lies in the fact that so large a proportion of the material in a given sample, regardless of the variation in the grindability of the components, is ground to such a fine size that the hard material cannot remain unground. On the other hand, with the Hardgrove method only the softest components are ground to the finer sizes, where they necessarily reflect inordinately large surface values and hence grindability values.

Volume of Mill Feed

The efficiency of any grinding mill depends on the amount of material being ground. The two tentative methods proposed specify that they are intended for use in determining the grindability of coal. When another material with a widely different density is placed in the mill the volume occupied by the charge necessarily varies. Consequently the effectivness of the mill also varies. With extreme differences in the bulk density of the charge, the grindability values obtained are not comparable. Under such conditions, grindability tests

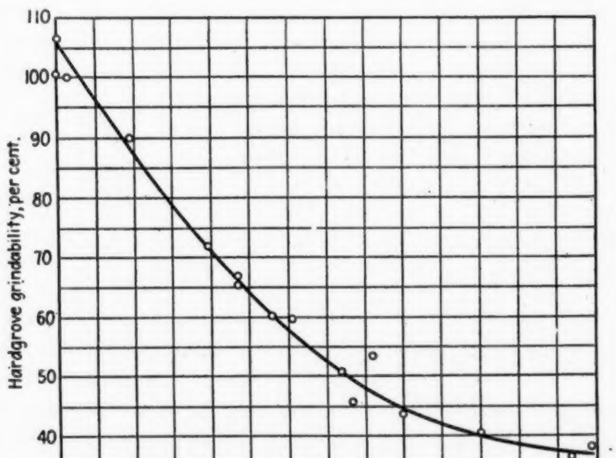


Fig. 1—Relation of Ball-Mill and Hardgrove-Machine Grindability Values

should be made upon equal numbers of particles per mill charge; that is, upon equal volumes of charge rather than upon equal weights.

Table III shows the results of the grinding tests made upon equal volumes of five coals by the ball-mill and the Hardgrove methods compared with the previous tests made upon equal weights of the same samples. Coals 1, 2 and 3 do not show significant differences between the volume and weight bases, because the standard volume of these coals weighs about 500 grams. However, coals 4 and 5, one a semi-anthracite and the other an anthracite, do show significant differences. For example, coal 5, which had a grindability of 31 by the ball-mill method on an equal-weight basis, has a grindability of 25 on the equal-volume basis.

TABLE III

RELATIVE GRINDABILITIES OF EQUAL VOLUMES AND EQUAL WEIGHTS OF FIVE COALS BASED ON COAL 1 AS 100 PER CENT

Coal No.	Weight of Std. Volume, Grams	Relative Grindability Ball Mill Volume	Ball Mill Weight	Hardgrove Volume	Hardgrove Weight
1	513	100	100	100	100
1	496	56	56	68	67
3	516	49	51	58	60
4	540	41	44	47	51
5	633	25	31	28	36

Relationship of Methods

Fig. 1 shows ball-mill grindability values plotted against Hardgrove values for a group of 16 coals, covering a wide range of grinding characteristics. The shape of the curve shows there is no simple relationship between the results obtained by the two methods. However, approximate conversion from one method to the other is made possible by use of the curve. The method of converting ball-mill values to Hardgrove values by multiplying the reciprocal of revolutions by 72,000 is obviously erroneous.

Investigation of C.I.T. Roll Test

The C.I.T. roll-test method recently proposed possesses attractive features; tests are easily and rapidly performed. In brief, a sample of sized coal placed on a flat steel plate is crushed by rolling a heavy steel cylinder over it 10 times. The crushed product is then screen-sized, and the new surface produced is calculated from the screen analysis. In principle, the method belongs to the classes of constant-work methods, such as the Hardgrove, and is subject to the same criticisms.

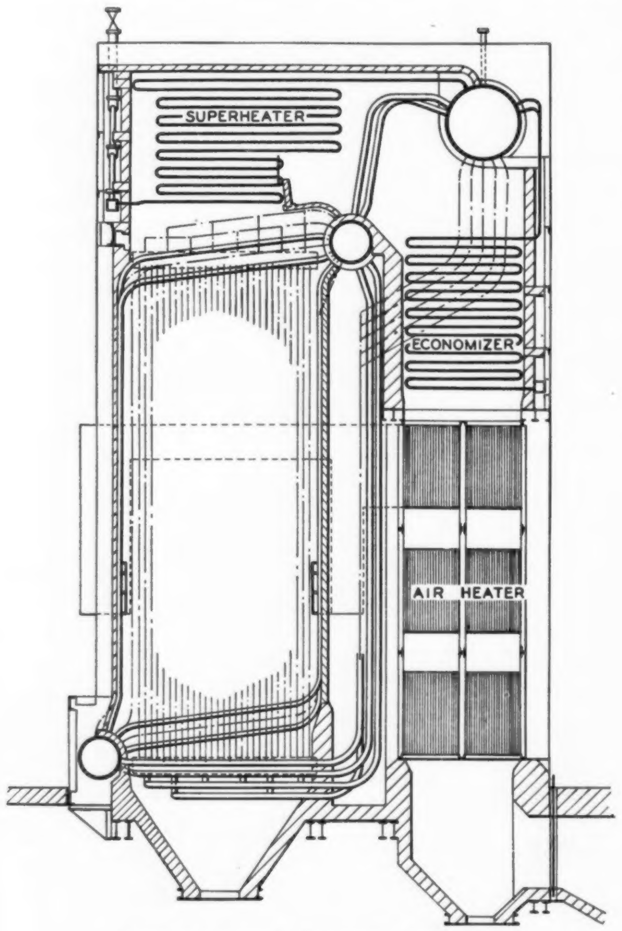
Conclusions

The C.I.T. and Hardgrove methods specify a constant amount of work on each sample and attempt to estimate relative grindability from an approximation of the new surface produced by grinding only a small proportion of the sample to a fine size. The ball-mill method is a direct procedure involving measurement of the relative amount of energy required to grind coal to the size actually burned as powdered fuel.

The investigation showed that coals are mixtures of components, each of which requires a different amount of energy to grind. Relative grindability results cannot be accurate unless equal proportions of these components are ground to the size suitable for use as powdered fuel. This is accomplished by the ball-mill procedure, but not by either of the constant-work methods.

The Cantieny Boiler

A design of high-pressure boiler that is attracting considerable attention abroad is the Cantieny, built in Germany by the Kohlenscheidungs-Gesellschaft and lately introduced into England by International Combustion, Limited. Several installations are completed or under construction in Germany for pressures ranging from 600 to 1950 lb per sq in. and outputs up to 350,000 lb of steam per hour. That shown in the accompanying sketch was recently put into service.



Section through Cantieny boiler unit

The essential features of this design center about the circulation system, the aim being to secure, with natural circulation, a positive flow with high pressures and avoid priming or carry-over when the boiler water contains a high concentration of solids. This is accomplished by providing a substantial separation between the ascending steam and the descending water. Referring to the sketch, there is a primary heating surface, made up of the tubes immediately surrounding the furnace, in which the circulation is upward on all sides from the lower left-hand drum to the upper (right-hand) water drum. Downcomers from the latter and from the steam drum, which are located outside the primary furnace tubes, supply the lower left-hand water drum or header. The tubes leading from the upper drum to the steam drum are so proportioned that circulation is throttled to the end that the water-steam mixture at normal ratings is separated and substantially water-free steam passes to the steam drum where it is introduced above the water line. There are also furnace side walls in which the circulation is similar to that of the front and rear walls. In all furnace walls the flow paths of water and steam between the lower and upper drums are symetrical and of uniform length.

All the tubes entering the drums are evenly spaced over the full length and there are no tubes of boiler, superheater or economizer entering the drum ends thus eliminating all end flows. Apparently concentration builds up in the water circulating in the furnace walls which must be taken care of by blow-down.

Various modifications of the arrangement here shown have been employed in the several installations made but all employ the same principle.

Lectures on Metals

Johns Hopkins University, Baltimore, is giving a series of Wednesday evening lectures on "Metals used in Engineering Practice." They cover the properties of important metals and alloys with particular reference to recent developments. The lectures are open to the public and are intended for engineers, plant managers, designers, foremen, etc. Two of the seven lectures have already been given. That on March 18 will deal with "Heat Treatment of Ferrous Metals"; on April 1 "Failures of Ferrous Metals by Fatigue, Corrosion and Creep" will be discussed; "Ferrous Alloys" is scheduled for April 8; "Non-Ferrous Metals and Alloys, Brasses and Bronzes" for April 15; and "Non-Ferrous Alloys—the Aluminum, Magnesium and Beryllium Series" for April 22.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

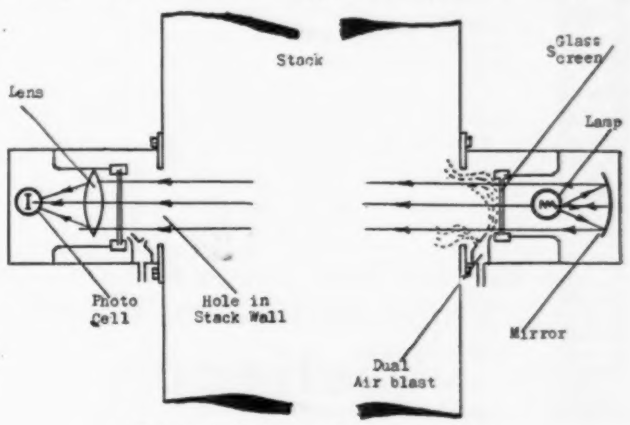
New British Pulverizing Mill

Reporting on the exhibits seen at the recent British Industries Fair at Birmingham, *Engineering* of February 14 describes a new ring-roll mill put out by the British Rema Manufacturing Company. A vertical section of this mill is here reproduced. The grinding system consists of a semi-steel casing in which is housed a free-running grinding ring *a*. This ring is suspended from and is driven by the top crushing roll *b* which, in turn, is mounted on a driving shaft carried in external dust-proof roller bearings. At the lower part of the ring are two more crushing rolls *c* which are mounted on floating shafts.

The centers of these three rolls are located at the corners of a triangle, their relative positions being maintained by external springs which exert an outward thrust so that the two bottom rolls bear against the rings and are rotated by it. The coal being ground is caught between the three rolls and the inner surface of the ring, the springs yielding in accordance with the size of the material. The springs have adjusting screws to compensate for wear. These adjusting screws are said to require attention at intervals of about 500 hr running. One machine has run for 15,000 hr grinding Kent coal without the ring or rolls having to be replaced. The power consumption with bituminous coal is given as 8 kwh per ton with a fineness of 65 per cent through a 200 mesh and 11.5 kwh per ton pulverized with 80 per cent through the same mesh.

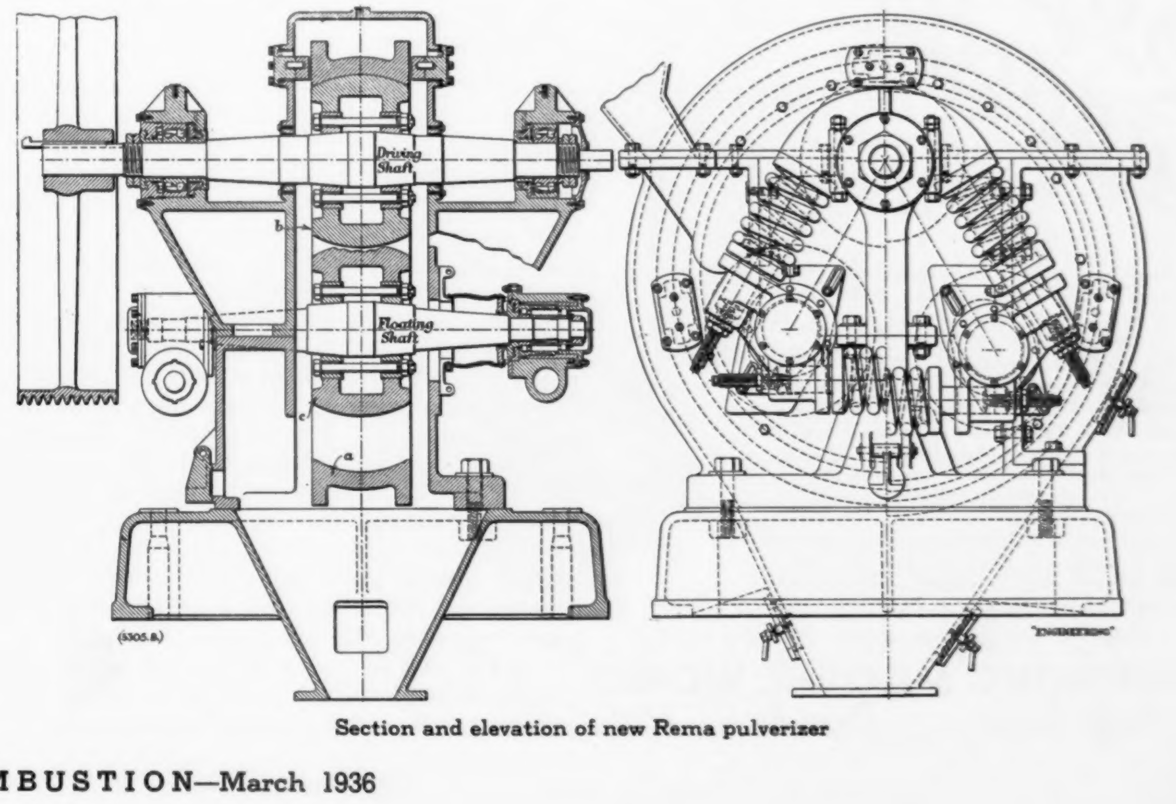
Radiovisor Smoke Indicator

Engineering and Boiler House Review (London) for January describes a smoke indicator, in principle not unlike some that have been brought out in this country in which the rays of light from a lamp, projecting through a glass screen at one side of the stack, pass through the stack gases, a lense on the opposite side, and converge on



A jet of air keeps the screen clear

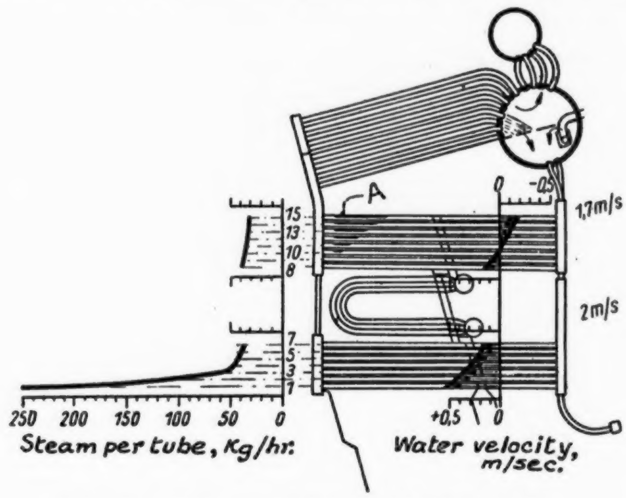
a photo-electric cell which records the intensity of the light reaching it, which is thus a measure of the smoke density in the flue. An interesting feature of the arrangement is two air jets, one on either side, which impinge on the glass screens and keep the glass clean.



Section and elevation of new Rema pulverizer

German High-Pressure Boilers

There are now in service in Germany forty-one boilers operating at pressures of 1400 lb or over, according to an article by O. Schöne in a recent issue of *Wärme*. Most of these have been installed during the past two years. Of the total, eight are Benson boilers, seven Schmidt design and five Loeffler units; of the remainder twenty are of the steeply inclined type and one a sectional header. The author, among other things, discusses steam accumulations, dissociation and corrosion, pointing out that a definite circulation is desirable in all tubes. In this connection he presents the accompanying illustration showing water velocity curves for a straight tube sectional-header boiler in which corrosion occurred in the upper tubes at *A* due to reverse flow and dissociation of the steam. The difficulty was overcome by fitting plugs, each containing an orifice at the ends of the tubes affected.



Water velocity curves for straight-tube boiler

Control of Energy Production Proposed in Germany

To date there have been conflicting opinions between the press and producers of energy, as to costs and rates, monopoly and competition, gas and electric service, all of which has led to the conviction that only a state authority can handle the problem to the best interests of the whole public.

In the present setup, the state group supervising energy production and distribution in Germany is only advisory without power to enforce its recommendations. *Wärmerwirtschaft* of January contains a digest of the pending law which was announced by Dr. Schacht several months ago before the Annual Meeting of the electric power producers. This views the production and distribution of energy as basic to the industrial and social life of the nation and provides for supervision and control under the minister of industry who will pass upon the closing down of power stations as well as new construction. Isolated plants will not be required, in general, to report and obtain such approval although cooperation among power producers will be the aim.

In the same issue appears a recent lecture of Von E. Shulz before the V.D.I. supporting this opinion and reviewing such control in several countries.

JAMES WATT

A Discussion

I have read with interest the contribution under the above title in the January issue by H. R. Taube. It would be impossible for me in any reasonable space to contradict all the assertions made, but I will deal with the question of the "Cornish" boiler. Where Mr. Taube got his information that Watt improved the "Cornish" boiler is to me a mystery.

With regard to the statement attributed to Watt, "that the inventor of the 'Cornish' boiler is unknown," I suggest this was a a deliberate untruth and that he knew perfectly well who was the inventor, that it was his opponent, Richard Trevithick, who was also a much greater engineer.

I do not wish to depreciate the achievements of Watt, but he was obviously devoid of imagination and business ability to a grotesque degree. For some mysterious reason he could never be made to understand that his engine and boiler operating at 5 to 6-lb pressure was an impossible proposition because of the weight per unit output of power. It is a misstatement of fact for Mr. Taube to claim that the Watt engine was an economical source of power. What must have been the thermal efficiency with the ridiculous externally heated "wagon" boiler merely a closed tank operating at about 6-lb pressure, and the badly cramped flues and a small chimney belching forth black smoke continuously?

It was for this reason that James Watt and the firm of Boulton & Watt fought unscrupulously to prevent the use of steam at pressures higher than about 6 lb, which Watt regarded as the final limit for all time.

Watt was also a bitter opponent of the steam locomotive as well as of the marine steam engine, simply because his engine was worthless for the purpose, due to its weight. Thus, he prevented his famous employee, William Murdoch, from being one of the pioneers of the locomotive, and although toward the end of his life the firm of Boulton & Watt was compelled to raise the steam pressure to 10 lb they did this reluctantly.

In my opinion the greatest engineer in the history of steam was Richard Trevithick, who invented the "Cornish" cylindrical boiler in 1797. Trevithick realized clearly that the future of steam lay with higher pressures and accordingly he invented the internally fired cylindrical boiler, which he named the "Cornish" after his native county. By using this principle he was able to raise the pressure to about 25 lb, and he constructed at the Cook's Kitchen tin mine in Cornwall what may be described as the first modern boiler and power plant in the world, consisting of a "Cornish" internally fired cylindrical boiler operating at about 25 lb and an advanced design of condensing beam engine.

James Watt was bitterly opposed to the "Cornish" boiler and still clung to his "wagon" design, which was merely the old "haystack" boiler of the Newcomen engine extended in length and fired underneath like a kettle, although certainly flues were built around the boiler in an attempt to increase the rate of heat transmission. In my opinion there is no justification whatever for the statement that Watt improved the "Cornish" boiler, and, further, these boilers were never made square or rectangular with flat sides, but always on the cylindrical principle. There are one or two fine examples of the original "Cornish" boiler, as made by Trevithick, in the South Kensington Museum (London).

It was because of this boiler that both the locomotive and the marine steam engine became a practical possibility. Trevithick was the great pioneer of the locomotive, having constructed in 1801 the first successful locomotive, which ran up the steep hill at Carn Brea, near Camborne (Cornwall) and back again. Following this he constructed his famous "Catch-me-who-can" locomotive, while in 1803 he constructed the first steam railway in the world, between Penydaran and Quaker's Yard, Merthyr Tydfil, hauling coal trucks over a track of about ten miles.

The "wagon" boiler of James Watt soon became obsolete and was replaced everywhere by the cylindrical "Cornish" boiler, while the pressure was gradually raised in spite of all that Boulton & Watt could do. Trevithick is stated, for example, to have actually worked at 160 lb, taking his life in his hands in the process, and he prophesied that some day boilers would operate at 200 lb as a commercial proposition.

DAVID BROWNLIE, London, Eng.

A Reply by H. R. Taube

It seems to me that Mr. Brownlie's comments dealing mostly with Trevithick, have only a very remote connection with my article on James Watt. His criticism of some passages in this article is not substantiated by facts or, as in the case of the Cornish boiler, is based on his failure or, perhaps, unwillingness to understand what I was talking about.

While it is customary to apply the name "Cornish" to the circular boiler with internal flue introduced by Trevithick, it should be quite clear from the context that the boilers "common with Cornish engines" adopted by Watt are not identical with Trevithick's boilers. It might not have occurred to Mr. Brownlie that I called these boilers, developed and first applied in Cornwall, "Cornish," as I might have spoken of American or German boilers, for the reason that they *were* Cornish boilers. It is, however, beyond my understanding that he could have mistaken for Trevithick's circular boiler one described as having "a flat bottom and flat sides, tied with stays," and to which Watt refers as having been used "before my time," in other words before 1771, the year Trevithick was born.

Mr. Brownlie describes the "ridiculous" boilers used by Watt as "closed tanks" and states that these boilers "were fired underneath like tea-kettles, although certainly flues were built around the boiler. . ." These remarks show his lack of understanding of the fact that the boilers used by Boulton & Watt, as well as their Cornish models, had flues "through which the flames were conveyed in the inside of the water," as Watt expresses it. I would suggest that Mr. Brownlie consult Dickinson and Jenkins' "James Watt." The reproductions in this book of boiler drawings made by Boulton & Watt will interest him and, perhaps, even convince him that Trevithick's boiler, though an important improvement, was in fact only a modification of a long-known type.

Mr. Brownlie is probably also mistaken in his statement that Trevithick named his circular boiler "after his native country." Dickinson and Titley in their Trevithick memorial volume (Cambridge, 1934) remark that the horizontal, circular boiler with internal flue was originally known as "Trevithick's boiler," and that the name Cornish boiler appeared only in the eighteen hundred twenties, during Trevithick's absence in South America.

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(*Continued from page 43*)

Trevithick has no claim to the priority in the use of higher boiler pressures. Papin and Savery among others, used them a century before Trevithick. The comparatively high pressures used by Savery in his pumps were responsible for their failure, on account of several disastrous boiler explosions which completely discredited his invention.

Mr. Brownlie seems to forget that Trevithick entered the field of steam engineering about 25 years later than Watt. During these years enormous progress had been made in the mechanical arts and metallurgy, progress which was in no small degree due to the influence, direct or indirect, of Watt's activities and, in consequence many things could be done in 1800 which were impossible in 1775. We would not form a high opinion of the intelligence of any one attempting to ridicule the engineers of the beginning of this century for not having used the high pressures common today. These men had a clear understanding of the great advantages of such pressures but refrained, like Watt, from using them for the valid reason that it was not yet safe to do so.

Mr. Brownlie takes me to task for the "grotesque misstatement" that "the Watt engine was an economical source of power." His quotation is not exact and, apart from its context, it does not convey the meaning that I had intended. What I did say was that it was Watt's great achievement of "having transformed Newcomen's wasteful pumping engine into a versatile, efficient and economical source of power." This statement does not, of course, refer to the engines built by Boulton & Watt during Watt's lifetime, but in a wider sense to the fact that the reciprocating engine based on the principles and devices introduced by Watt became and remained for over a century the most economical source of power available.

Mr. Brownlie insists emphatically that Trevithick was a greater engineer than Watt, and the "greatest engineer in the history of steam." As there exists no generally accepted yardstick for measuring the greatness of engineers, it is impossible to argue this point. Mr. Brownlie is certainly entitled to his opinion. After all, the Watt-Trevithick controversy is a dead issue.

In conclusion, I fail to find in my article any statement to the effect that Watt was the inventor of the steam engine.

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